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INTRODUCTION TO STREAM NETWORK HABITAT ANALYSIS

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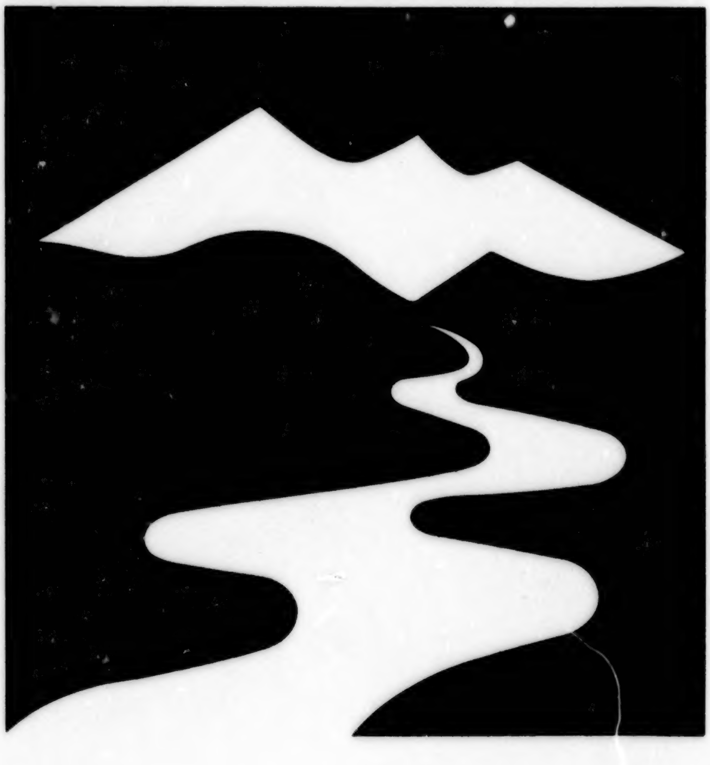

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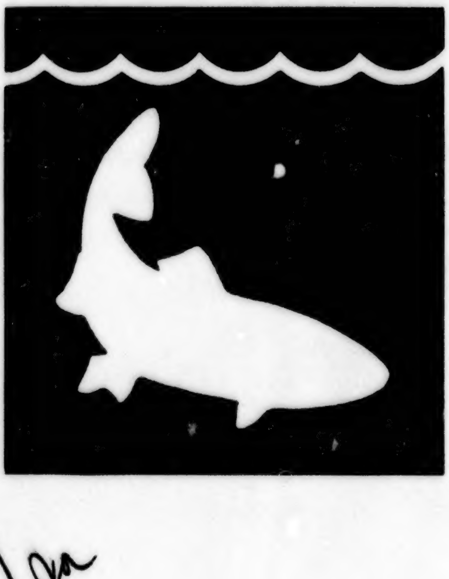

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INTRODUCTION TO STREAM NETWORK HABITAT ANALYSIS

Instream Flow Information Paper 22

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PREFACE

The Instream Flow Incremental Methodology (IFIM) has been defined in a variety of ways, most far more complicated than necessary. In essence, IFIM is a reasoned approach to solving complex streamflow allocation problems that are often characterized by uncertainty. Application of the IFIM requires an open and explicit statement of management goals, study objectives, technical assumptions, and alternative courses of action. IFIM provides a framework for presenting decisionmakers with a series of management options, and their expected consequences, in order that decisions can be made, or negotiations begun, from an informed position. IFIM exposes for the decisionmakers those areas where their judgment is necessary and presents the potential significance of the alternatives they might choose.

As awareness of the impact of man's activities on his environment has grown, recognition of combined environmental effects has heightened. Various terms such as combined effects, cumulative impacts, and synergism have been coined to describe this class of problems. The issues of spatially and temporally cumulative effects as applied to aquatic habitat created the need for anlaytical tools to describe such effects. The use of such tools allows the logical extension of the decision support concepts of IFIM into the area of branched stream network analysis. It was the demand for such a set of tools that led to development of the concepts and computer programs described in this document and to the use of the term "stream network habitat analysis."

This manual is intended as both an orientation to stream network habitat analysis and documentation of a library of computer programs developed to aid in such analysis under the specific conditions defined below. We have anticipated that readers of this document will have a wide range of experience in modeling and habitat analysis. Users who have limited experience in model development and application are encouraged to read sections 1 and 2 before proceeding on to the later, more application oriented, sections. Those experienced readers who are familiar with modeling and habitat analysis techniques may wish to skim sections 1 and 2 just to get the flavor of our thinking before reading sections 3 and 4 in depth.

Section 3 discusses the individual components of a network analysis. Each of the kinds of models employed is examined briefly, with examples of those models and some alternatives laid out. Particular attention is given to those models we have used in our analyses.

Section 4 covers guidelines for formulating basinwide water management recommendations tailored to management of aquatic habitat. It introduces the considerations necessary to help ensure the analysis is congruent in the biological and hydrological domains. Finally, it provides a brief review of the experience gained in application of some of the available technologies to real-world problems. These technologies consist largely of conceptual models and computer programs that make up the main tools for network habitat analysis and display.

Section 5 presents an example problem for a hypothetical river basin. The problem is given to illustrate the sequence and use of many of the tools discussed throughout the paper. Though this example is not intended to be all encompassing, it is meant to represent one commonly confronted type of analysis situation.

The very nature and scope of basinwide analysis problems preclude coverage of all possible contingencies. The tools presented here are oriented to steady-state, monthly time-increment problems. This class of problems constitutes the bulk of past and probable future studies, but does not represent exhaustive coverage of the potential range of studies that may be needed. Comments and guidelines for determining when a steady-state analysis is not appropriate are included in the document.

This document has been prepared for use in a classroom setting. Supplemented by other material and case studies, the text is meant to help form a background for both classroom discussion and hands-on computer use. The appendices document a set of computer programs useful in performing a stream network habitat analysis. They do not stand alone, but rather should be viewed as a set to be added to the growing collection of analysis tools already in one's repertoire.

Questions or comments concerning stream network habitat analysis should be directed to: Leader, Instream Flow and Aquatic Systems Group, National Ecology Center, 2627 Redwing Road, Fort Collins, CO 80526. Telephone: (303) 226-9331; FTS 323-5331.

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We would like to thank the supporters and reviewers of this project for the patience and feedback provided. The Denver Regional Office of the U.S. Fish and Wildlife Service has been a fertile testing ground for the ideas and computer programs documented in this publication. Without their faith that the Upper Colorado River Basin could be somehow captured in a network-wide model, the experience gained and tools created would not have come for many years. Frank Dunkle is to be thanked for his foresight and trust in modeling. John Hamill continues to be an ardent supporter of an organized approach to habitat analysis. We thank Bob Green, George Smith, Mike Brewer, George Bowen, and Sue Zirbes for being competent users of many of the tools we have been advocating.

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1. INTRODUCTION

Increasing demands on stream resources by a variety of users have resulted in an increased emphasis on studies that evaluate the cumulative effects of basinwide water management programs. Network habitat analysis refers to the evaluation of an entire river basin (or network) by predicting its habitat response to alternative management regimes. The analysis principally focuses on the biological and hydrological components of the river basin, which include both micro- and macrohabitat. (The terms micro- and macrohabitat are further defined and discussed later in this document.) Both conceptual and analytic models are frequently used for simplifying and integrating the various components of the basin. The model predictions can be used in developing management recommendations to preserve, restore, or enhance instream fish habitat.

A network habitat analysis should begin with a clear and concise statement of the study objectives and a thorough understanding of the institutional setting in which the study results will be applied. This includes the legal, social, and political considerations inherent in any water management setting. The institutional environment may dictate the focus and level of detail required of the study to a far greater extent than the technical considerations. After the study objectives, including species of interest, and institutional setting are collectively defined, the technical aspects should be scoped to determine the spatial and temporal requirements of the analysis. A macro level approach should be taken first to identify critical biological elements and requirements. Next, habitat availability is quantified much as in a "standard" river segment analysis, with the likely incorporation of some macrohabitat components, such as stream temperature. Individual river segments may be aggregated to represent the networkwide habitat response of alternative water management schemes. Things learned about problems caused or opportunities generated may be fed back to the design of new alternatives, which themselves may be similarly tested. One may get as sophisticated an analysis as the decisionmaking process demands.

Figure 1 shows a decision point that asks whether the results from the micro- or macrohabitat models display cumulative or synergistic effects. If they do, then network habitat analysis is the appropriate tool to employ; if not, simple river segment analysis is the appropriate tool. We are left, however, in a difficult bind. We may not know a priori whether the effects are cumulative or synergistic unless some network-type questions are investigated as part of the scoping process. The next several sections raise issues designed to alert the modeler to relevant questions necessary to address this paradox.

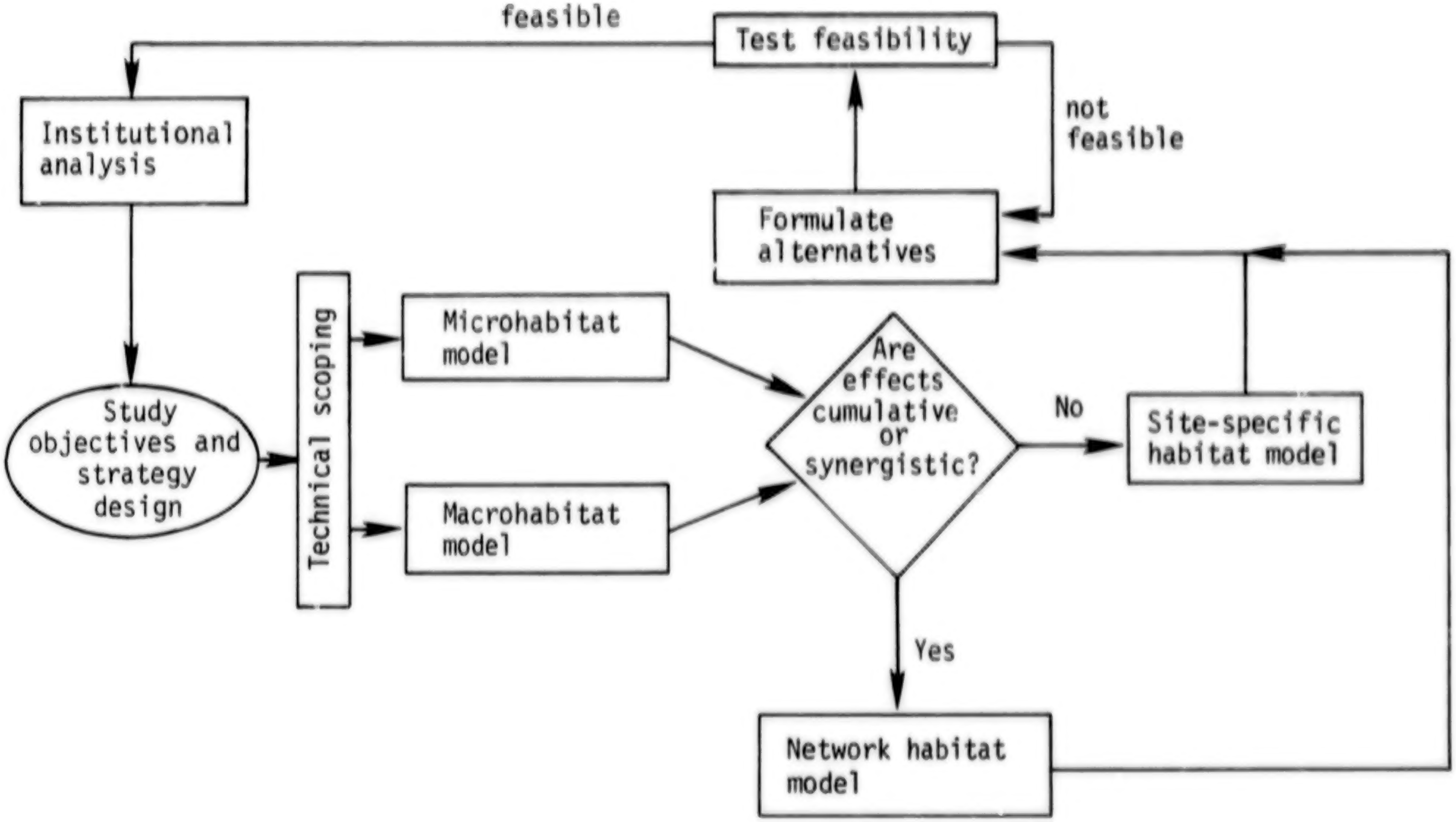

Figure 1. Relationship of network habitat analysis to site-specific habitat analysis.

1.1 WHY NETWORK ANALYSIS?

The primary goal of network analysis is to assemble and integrate the necessary technical information to support water management decisions to protect, restore, or enhance aquatic habitat throughout a river basin. Network habitat analysis is necessary because of its utility for analyzing a complex basinwide aquatic system. Many commonly used analyses involve aquatic systems of limited scope. For example, most applications of the Instream Flow Incremental Methodology (IFIM) deal with site-specific analyses. The typical study may consider a single river segment in a simple linear stretch downstream from a single reservoir or irrigation diversion. Relevant questions arise, however, concerning the cumulative effects of instream and offstream basinwide water management on aquatic habitats.[1] In network habitat analysis, we are not examining a single river segment, but a network of interconnecting waterways that should be examined collectively.

But what is it that truly distinguishes a network analysis from a simple river segment (site-specific) analysis? First, a single water management project may have impacts widely dispersed through time and space. The spatial part is easy to see--any habitat site downstream from the project has the potential to be impacted. Temporally, the effects from a single project may be due to lags in the delivery of water, such as through irrigation system return flow or carry over of storage in a large reservoir.

It is multiple projects distributed throughout a dendritic river network, however, that provide the best examples of how a network analysis differs from a segment analysis. Multiple projects may have cumulative and synergistic effects on habitat widely distributed throughout the basin. A commonly cited example is the case of water temperatures that are closely tied to upstream events. Instituting a new reservoir with its new reservoir release temperature on one tributary, combined with a new operating schedule for an existing facility on a related tributary, may interact to modify downstream temperatures in ways that neither project could have done by itself.

Another distinguishing feature of network analysis is illustrated by situations in which the physical structure of the network is being altered in some way. Construction of diversion facilities on one stream with returns on another can serve to shift flows, and thus aquatic habitat, from one tributary to another. Transbasin diversions in the intermountain West provide excellent examples of this type of habitat alteration.

Habitat concerns may play as important a part as water management concerns in dictating the need for network analysis. In situations where the habitat needs of a species are distributed through space, requiring the species to move from place to place through time, network analysis can be a valuable tool.

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[1] We have chosen to model aquatic habitat rather than population responses due to the difficulty involved in simulating measurable population responses. However, some problems will require population analyses.

Finally, one other case deserves special attention. The situation where the operation of one reservoir is in some way contingent on the operation of one or more other reservoirs is much more easily handled in a network approach. Even if the reservoirs are arranged serially, the contingencies, and their feedbacks, can be explored with greater ease by using models developed to handle the networking cases. In such situations, the effects on habitat of combined reservoir operations can be directly shown using network models.

Just as a site-specific application of IFIM calls for matching the biological analysis to the institutional setting, any basinwide analysis also must be driven by an understanding of the institutional setting and the key players involved. The institutional framework includes the economic, social, and political forces that shape any problem analysis. It may dictate that water management be approached basinwide, or even across multiple basins in the case of transmountain diversions, multibasin jurisdictions, or compact agreements. Just as water management decisions are made from a basinwide perspective, so must the biological decisions and recommendations be made, because they are one component of the whole water management plan.

A basinwide perspective of the biological component of a resource management problem causes the relevant considerations to multiply. No longer is the typical analysis confined to a single small area, species, or activity. Instead, questions now emerge dealing with what may be termed biological connectivity. An important concern is the movement of populations of species throughout the basin and matching requisite habitat components for each life stage through both time and space. Also, the more complex problems of tradeoff analyses arise: Are you willing to sacrifice habitat for a species in one geographic area to preserve or improve habitat in another area? What is the significance to the populations you are trying to manage that juvenile fish habitat is in excellent shape in some areas of the basin and simultaneously depressed in other areas under either natural or managed regimes? Can migration be facilitated in some populations to capitalize on the potential habitat available in particular locations?

A basinwide analysis should be approached in the order of the most critical controlling variables. Thus, for example, the presence or absence of stream flow, toxicants, migration barriers, etc., can clearly be considered the most fundamental and critical macrohabitat variables (and indeed may be the critical decision variables) when a project proposes dewatering a stream for some distance.

Looking at alternative water management scenarios and translating those alternatives into their consequences on the physical components of habitat quality can be a difficult task for a single reach of stream. The task is compounded for a network analysis in terms of tabulating the collective effects for multiple species, life stages, timeframes, and geographic locations. The critical step here is to determine basinwide changes in macrohabitat caused by changes in upstream conditions.

Network habitat analysis helps to evaluate the habitat implications of basinwide water management. The advantages can be tremendous in terms of the ability to study a complex system; however, the costs can be high in terms of time, money, and manpower. Costs will depend on the experience of the analysts, precision required, and documentation produced. The demands on resource analysts are great; expertise must be used from many disciplines. The breadth and complexity of the issues involved heighten the need for ingenuity and critical thinking. Guidelines are necessary to make intelligent decisions in weighing the rewards versus the risks.

Macrohabitat vs. Microhabitat

Network habitat analysis involves the evaluation of biologic responses on two levels: macrohabitat and microhabitat. Their distinction is largely a matter of resolution.

Stated simply, macrohabitat characteristics are those that are longitudinally distributed more or less uniformly and unidimensionally throughout a stream segment (Bovee 1982). There are usually no sharp gradients of macrohabitat characteristics within longitudinal distances greater than or equal to 5 to 7 times the stream width. For a network analysis, macrohabitat usually refers to entire stream segments many times longer than the stream width. Macrohabitat characteristics often control the distribution within a stream system of a given mix of species. Some examples of macrohabitat variables that may determine the suitability of a reach of stream for habitation are passage blockages, temperature, dissolved oxygen, organic input (nutrients), and the concentration of dissolved materials, particularly toxic compounds.

Macrohabitat is often highly sensitive to cumulative effects. Stream temperature, pollutants, or other water quality parameters display synergistic effects, which typify the need for a network analysis. The most obvious illustration, as we have previously mentioned, concerns downstream water temperatures, which are at least partly a function of upstream conditions. In a dendritic network, it is easy to see how temperature effects from multiple tributaries result in mainstream temperatures different than those that result from a simple averaging of the tributary temperatures.

In contrast, microhabitat characteristics refer to point-specific conditions that influence the local distribution of fish and other aquatic organisms (Stalnaker 1979). This description is further limited to specific physical characteristics for the remainder of this discussion. These are unique combinations of depth, velocity, substrate, cover, or other very localized conditions that seldom occur with linear dimensions greater than feet, and usually much smaller. Their aggregation over a representative length of stream (such as two or more pool-riffle sequences), however, provides an indicator of the physical habitat quality of the stream segment (Bovee 1982).

1.2 WHY MODELS?

Models are useful because of their ability to represent reality in a simplified manner. The value of models in network analysis is, first, in understanding and, second, in predicting situations where it is not possible to experiment with the real world (Lee 1973).

The best models are easily understood and provide a reliable approximation of how the natural system works. Furthermore, good models are widely applicable; that is, they function well in a variety of situations and are not intimately tied to any single set of conditions. Unique or abnormal conditions must be properly incorporated. The models are sensitive to gaming with a reasonable set of management actions. Finally, there must be adequate documentation of the model. The challenge is in acquiring and using models that are comprehensive and detailed enough to represent the situation, yet are not too complex or data intensive to be applied. Whether we realize it or not, decisions are based on models, and these decisions can usually be improved by making the models more explicit. From this perspective, the crucial question becomes not whether to use models, but which models to use. Once selected, the quality of model implementation depends highly on the time and financial resources available, as well as the knowledge and experience of the modeler.

The common denominator of the models used in network habitat analysis is that they only approximate how the world works and fits together. However, they provide a consistent framework for communication among investigators and decisionmakers that has enormous benefit in simply helping to understand the problem. The framework not only aids in communication of perceptions about the system, but also serves as a means for identifying and organizing the appropriate "what if" scenarios to be evaluated. "What if we operate this reservoir with this pattern of flow in dry years?" "What if we remove a migration blockage here and open this watershed to migrating fish?" In this sense, models have gained much respect in being able to "game" with a system by hypothesis rather than game with a system in reality, with the attendant costs or risks of doing irreparable damage.

Models serve many other valuable purposes as well. They often are excellent lie detectors. When a strict set of rules is established for the system operation and then tested for "reasonableness," perceptions may not match the forecast. This is valuable in helping to either refine your understanding of how the system really works, or improve the data base, or both. Passing the "reasonableness" test (often called verification) leads logically to the "usefulness" test. The subject of model "validation" entails making use of your model(s) in some decisionmaking environment. Being highly precise is not the essence of model validation. Many times just having a model that provides an estimate of cause/effect relationships is a powerful ally when you face the prospect of negotiating water and habitat resource management issues. This is not an excuse to do a sloppy job in your simulation. It is instead a reminder that simply assembling the appropriate knowledge in an organized manner may be all that is necessary to resolve a particular situation. The model may not be "right," but a properly validated model does provide a dependable approximation based on the best information available.

2. CONSIDERATIONS IN NETWORK HABITAT ANALYSIS

In any analysis, a starting point must be defined. All too often we are tempted to dive in where our own expertise leads us. There are numerous factors, however, that should first be considered. Figure 2 shows a group of considerations applicable to network analysis over and above those concerns encountered in a "standard" IFIM analysis. That is, in addition to examining agency jurisdications, permit requirements and so on, we need to be especially cognizant of these other concerns. Naturally, there is overlap with considerations in a nonnetwork case, but the degree of influence for the listed items is considerably different in a network habitat analysis.

2.1 INSTITUTIONAL CONSIDERATIONS

Evaluating the institutional background in which the technical studies will be applied is an essential first step in network analysis. Following the IFIM philosophy in general, we should begin project scoping at the institutional level, giving appropriate consideration to the legal, political, economic, and social concerns influencing the basin. Network habitat analysis not only should follow this same philosophy, but specifically puts even more emphasis on beginning with an institutional analysis.

Institutional Considerations
  - Geographic Scope
  - Time Horizon
  - Existing Models

Spatial Considerations
  - Spatial Boundaries
  - Spatial Resolution
  - Matching Models

Temporal Considerations
  - Temporal Boundaries
  - Temporal Resolution
  - Matching Models

Resource Considerations

Figure 2. Considerations in framing a network habitat analysis.

First, the geographic scope of your models may need to be expanded beyond the purely biological "home range" to cover all water uses. Transbasin diversions, for example, may require you to be cognizant of water uses and users that may have no direct bearing on the species under consideration. Yet you will need to be conversant with the water needs of adjacent basins that will be included in negotiations. Similarly, if the existing or proposed project spans several political jurisdictions, you should be aware of the broader spectrum of players you may need to deal with. Remember that ultimately someone pays for all of the actions and effects of every project. Consideration of those people who bear the costs and those who reap the benefits, wherever they may be, will be to your ultimate advantage.

Second, the time horizon of a basinwide analysis may be quite lengthy. Big projects often have a long, clearly defined system life. The planning horizon, spanning all activities covered in the plan and all future conditions and effects of alternative actions influencing the planning decisions, is largely determined by economic criteria. As usual, it is advisable to be an early player--it is almost always easier to mold thought in the formation than it is to change an operation's plan once installed. From an institutional perspective, the long analysis period is also important. Continuity and progress are generally in flux. Individuals involved will be continually changing. Progress is slowed, putting greater emphasis on information transfer.

Finally, the large number of players involved may mean that locally accepted models (or data) are being used that must not be ignored. The Corps of Engineers (COE), Bureau of Reclamation (BOR), or water conservancy district, for example, may have existing hydrologic models to describe system operation. It would be foolish to unilaterally declare previously developed models inappropriate. The best action is to determine how to make the most of the existing models, adapting or supplementing their capabilities if necessary. You should be ready to accept the consequences that an adjustment in time step or geographic resolution may mean, or to supply analytical methods to expand an existing model's scope and resolution to address the biological issues at hand.

Addressing institutional considerations means taking a realistic look at the other players. Making an objective inventory and evaluation of the needs of other players will be a valuable guide to framing the technical issues.

2.2 SPATIAL CONSIDERATIONS

Networks cover areas larger than those in a simple stream reach problem. Two central questions must be answered when defining the spatial extent of a network analysis. How large an area must you consider (breadth), and how finely do you need to represent specific geographic locations (depth)? In addition to the institutional aspects noted earlier, there are both biological and hydrological components to these two questions. Network habitat analysis focuses on the biological questions first, then asks what you need to know from the hydrologic realm to be able to address the biological questions. For both breadth and depth, there will always be a gap between the data you should have and the data you will have. Ultimately, you should recognize that some decisions will be on weaker footing than others. All of these issues must be looked at from the view of the original study objectives, which may largely dictate the answers to each question.

Breadth: Spatial Boundaries

Most of the biological considerations dealing with spatial boundaries fall in the area of common sense. First, make sure that you are covering the entirety of the target species' habitat requirements. Each species and/or life stage may use separate, distinct geographic areas at different times of the year. If a species is migratory, the different life stages must have a means of traversing from one area to another. Both the existing and proposed range must be included in the case of a habitat restoration project or new species introduction. Should you decide that some area or life stage is to be excluded from the analysis, this should be clearly documented, along with the reasons for so doing. All parties should agree.

Another important consideration is the hydrologic coverage necessary to ensure that the flow-determined habitat response is adequately represented. All controlling or managed elements must be included. For example, a warm-water species that is never found in the upper reaches of a basin may be impacted by existing or proposed reservoir or diversion development in the headwaters. Inclusion or exclusion of particular tributaries from a hydrologic point of view is a more difficult issue. If there is no decision to be made concerning the management of that tributary, and the existing processes within the tributary are unchanging, it may be safely omitted from consideration, and treated as an input to the system being studied.

This situation is complicated somewhat if macrohabitat is being considered in the analysis. For example, stream temperature is determined in part by upstream conditions. Therefore, temperature modeling may require that the study boundary be extended to headwater areas of limited fishery concern because of the techniques required for temperature regime description.

There are numerous other considerations. We have mentioned transbasin diversions as a special case of expanding the network beyond the purely biological arena. Remember that one of the "outputs" required from most water management models is water availability or supply to the project targets. This implies that you know where the water is destined. Finally, and very pragmatically, data availability may determine the geographic scope of your network.

Depth: Spatial Resolution

After deciding the geographic boundaries of your study area, the next task is to determine the spatial resolution, i.e., how finely you need to divide an area to adequately cover each life stage's needs. This is primarily determined by the value of the resource, potential influence of development, and the institutional setting. Each river or stream will be parceled into representative segments and further divided into specific study sites. (Instream Flow Information Paper No. 12 (Bovee 1982) covers the theory and details of how to accomplish this portion of your work and need not be repeated here.) Few network studies will have the luxury of establishing study sites at every location where one should technically be placed--there simply is not enough time, money, or manpower available. Therefore, the real question becomes not where to set up a study site, but where you can get by without one.

In network terminology, locations of interest to a study are called "nodes." Nodes are precise locations at which either we make something happen or we need to know what would happen "if...." Nodes should be at reservoirs, tributary junctions, stream gages, and biological study sites, at a minimum.

The job of the hydrologic modeling effort is to adequately represent the hydrologic network so that flows are accurately described at the biological study sites. As mentioned earlier, we certainly want hydrologic nodes at reservoirs and diversions (where we intend to manage the flow patterns), and at gages (so we can use those data to either drive the flow model or measure its success).

Hydrologic models may also require nodes to be established at other locations. Nodes may be required at places where flows change, such as tributaries. Any tributary contributing more than 10 percent of the main channel flow should be considered in the flow model. What happens to a small tributary that is omitted by this rule? All other flow is typically considered to be lateral (groundwater) flow and distributed uniformly between points of known flow. Naturally, the hydrologist should think about this before he makes assumptions that are too liberal. There can be distinct changes in groundwater flow, especially at major geomorphological discontinuities. As a practical matter, determining changes in lateral flow is difficult and requires an experienced hydrologist.

Diversions and return flows will usually be handled as nodes. Often, an irrigation or other diversion is indeed at a specific point. Return flows may also be at a point, but more often they are truly distributed flows, similar to groundwater.

Finally, point source discharges must be considered. These nodes may include thermal effluents important for macrohabitat analysis.

Institutional considerations may reappear. For example, there may be existing river basin models used by the BOR or COE that have fixed nodes. Their advantage is that they probably come with data. Their disadvantage is that interpolation between nodes to extract data for other nodes you need may be required. At other times, "political" nodes may be added to facilitate discussion with other interested parties. Using generic, data-defined models will often be the more flexible approach, and may provide a means of interpolation. The task in using generic models, however, is to acquire or develop the data necessary to run them.

So what about macrohabitat? Stream temperature modeling may require even more nodes to be established. For example, meteorological nodes may be mandatory if the elevation changes by 1,000 ft. If shading is important to temperature, stream reaches should be considered for division according to the attributes of the reach's orientation, topographic features such as cliffs, and changes in riparian vegetation. Any temperature gages, which may be separate from flow gages, must be included in your network of interconnecting nodes.

Matching Spatial Scope of Models

We have seen how each of the three main components (biological, hydrological, and macrohabitat) of network habitat analysis may have unique requirements for spatial extent and resolution. Each set of requirements should be overlayed to develop a composite schematic network definition as shown in Figure 3. Then, looking at this composite, it may be apparent that additional nodes are required, or that some consolidation may be appropriate.

At this point, review your schematic network and ask yourself if it appears sufficient to answer the biological questions posed. Remember that others will be scrutinizing your work. They must be satisfied that your model represents the real world as defined in your objectives. It is valuable to predefine the level of accuracy required in your analysis. For example, you may state that your temperature model will predict water temperature within 1° 95% of the time. This may dictate how finely to divide your network within cost constraints.

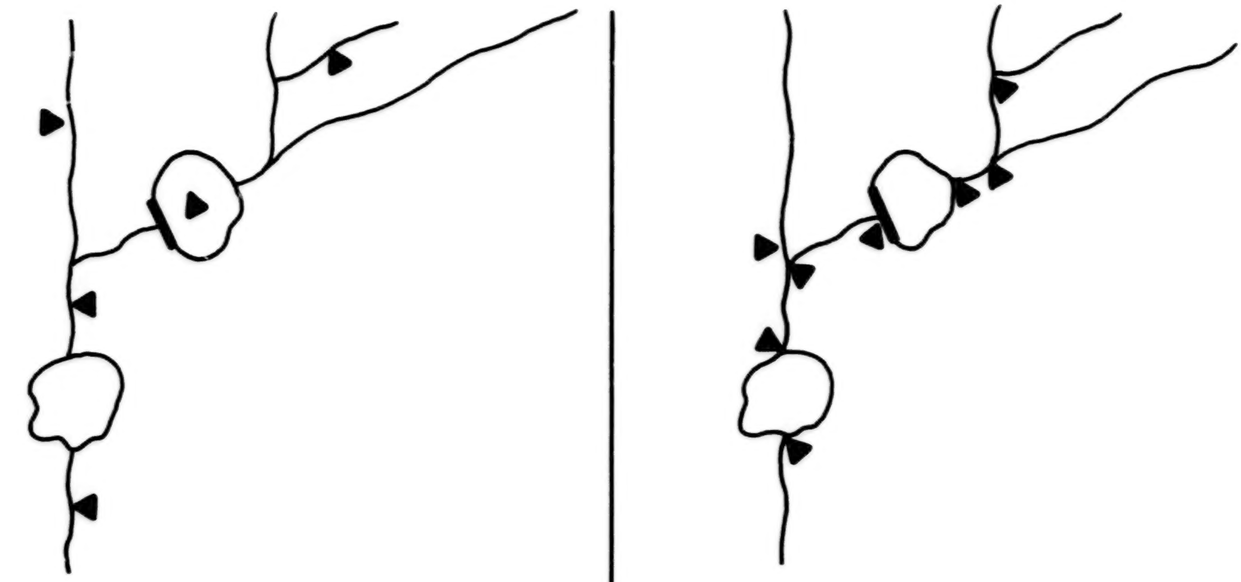
2.3 TEMPORAL CONSIDERATIONS

Before we proceed to outline temporal considerations, which are similar to the spatial considerations, distinction between steady-state and dynamic models must be understood.

Using the common definitions from hydrodynamics, a steady-state model of a hydrologic system rests on three assumptions: (1) the variables of interest act at an average, constant rate or remain "level" during the time increment in which they are evaluated; (2) changes in those variables between time and spatial increments are instantaneous at time step and nodal boundaries; and (3) the effects of the changes at the time step boundaries do not progagate in space or time. A steady-state model, for example, represents each day of a month-long period by the average values of the system variables over that time.

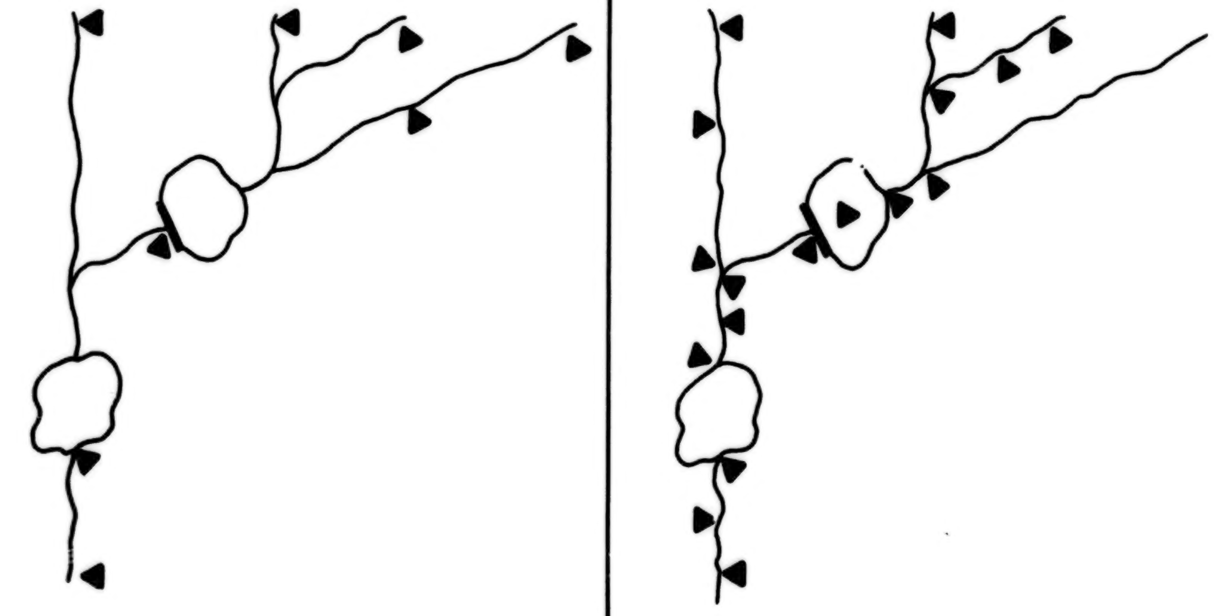
Dynamic models consider system response to the rate of change within a time increment. Thus, they allow the changes in study variables to mesh at time step boundaries, which means that effects may propagate over time.

Dynamic models are required if the problem involves the evaluation of peaking or pulsing reservoir operations, very high gradient streams, or other situations where rapid changes in rate of flow are likely. An example of a dynamic model is a simulation of a flood wave peak moving down a stream channel. Given information about the channel, the volume of the flood peak, and the rate of change in flow it induces, a dynamic model can track the wave downstream and account for the rise and fall of the crest explicitly. In contrast, a steady-state model may not even "see" the peak and simply treat a flood as a higher average flow over a given period, i.e., a week or a month.



Biological Nodes

Hydrologic Nodes



Macrohabitat Nodes

Composite System Representation

Figure 3. Composite network representation resulting from the three kinds of nodes.

When the flow situation dictates the use of dynamic models, care must be taken to ensure that relevant biological criteria can be brought to bear in the analysis. Quantitative species response relationships for rapidly changing flow conditions are scarce. The degree to which the network analysis will include collection of such data must be determined in the project scoping effort. Binary criteria (in this case placing a threshold at the maximum tolerable rate of change of velocity and, therefore, flow) may be the best that can be obtained. Without some dynamic response relationship, the dynamic flow simulation effort may be wasted. The data requirements of dynamic models are significantly higher than those of steady-state models.

Temporal Boundaries

Overall time boundaries, years of model simulation, are important institutionally because of the need for a benchmark. Many decisions will revolve around the central question of how the environment will be altered after a project is instituted. How should preproject conditions be characterized? One must have some benchmark period in mind for which the species being studied are shown (or felt) to be viable. Choice of a baseline period is critically important from a policy perspective. The years immediately preceding a project may not be a good baseline period because the species may not have been thriving. Thus, you may need to look back in time to more natural conditions in selecting the appropriate baseline. Conversely, a "virgin" condition baseline may not reflect current realities, e.g., dams are seldom removed, and thus natural conditions may be inappropriate to interpret in terms of contemporary management options. The concept of choosing an appropriate baseline is particularly important when dealing with endangered species. The issue of historical versus current range and the policy of goals concerning habitat maintenance versus enhancement or recovery must be considered carefully when designing an analysis. Fostering the idea that current conditions are acceptable could seriously undermine an agency's negotiating position in dealing with an endangered species' future.

Just as we need to look backward to determine appropriate baseline time periods, we need to look forward to the project's planning horizon to choose a postproject evaluation period. No one can predict the future, but we can categorize the probable events that may happen and make assessments based on logical risk analysis. This forecasting may take many forms, such as worst case analysis, which we will discuss later in this document.

After the institutional questions have been answered, proceed to the biological considerations in choosing your temporal boundaries. In most cases, species have evolved in particular geographic areas under a wide variety of circumstances. Extreme conditions, such as flood or drought, may often define the nature of the biotic community. Individual life stages may be more or less tolerant of the extremes encountered. Baseline or other evaluation periods must be long enough to capture the historic or projected variability naturally encountered. This annual variability must be captured both in terms of frequency of events and intensity of impact. In general, the pre- and postproject time periods used for evaluation should be of comparable length.

There are also temporal boundaries to be considered within a single year. Individual life stages undergo a rather fixed set of life cycle changes on a seasonal basis. There is no reason to be concerned with an entire year if only one life stage has been determined, from scoping or previous studies, to be the central issue. You must, however, be certain to look at seasonal windows that fully reflect the life requisites of that important life stage. For example, successful spawning may require the accumulation of a minimum number of degree-days for gonad development. Suppose gonad maturation requires water above 12 °C for 60 consecutive days. If so, you need to look from the spawning period back in time far enough to make sure that these macrohabitat needs are met.

Hydrologic considerations also must be considered in establishing temporal boundaries. Hydrologic baselines are usually defined by the precipitation events that are known to have occurred and the developmental history of the region. Reservoir development in particular requires much thought and analysis to determine carryover capacities. Again, the range of extremes determines the design and operation of any well conceived water management plan and, therefore, must be considered in your analysis.

The hydrologic planning horizon should be sufficient for biological purposes also, with only a few exceptions. Without proper input from biologists, events such as the following may be neglected: channel maintenance flushing flows; water needs for riparian vegetation, which may be very important in arid basins; and annual scouring and building of sandbars, which may be needed to prevent vegetation encroachment into the channel.

There is one additional time boundary consideration. As before, the range of natural variability must be considered. The most rigorous model validation (not often done) calls for calibration of one data set for comparison with an entirely separate data set. That is, one data set is "parameterized" by adjusting the appropriate variables. Then those same "set" variables are tested in the replicate data set to see if model performance is adversely affected. Each data set typically consists of a group of contiguous years. Because two data sets are required for this type of validation, the historical period may need to be extended. Likewise, the techniques of statistical hydrology need to be applied to record extension problems. A hydrologist familiar with record extension may extrapolate a period of known record to include a period of unknown record.

Temporal Resolution

Because we are dealing with steady-state models, distinct time steps must be specified. The size of the time step is important for several reasons. From a purely practical point of view, a larger time step requires less data. Imagine a single year being characterized by 4 seasons, or 12 months, or 52 weeks, or 365 days, or 8760 hours. For each variable of interest, the data needs increase from 4 observations per year to 8760. It is easy to see how we can quickly increase the size of data sets many-fold.

The larger the time step, the more that conditions of all sorts are averaged out and extremes are hidden. The smaller time steps can capture those extremes that may be critically important. For example, fry emergence may occur over a period of only a few days. Peak flow events averaged over a

1-month time step may not show up, yet they may mean the difference between 95% and 5% survival. Degree-day calculations can also be affected by the length of the time step. However, our ability to adequately simulate the physical system's behavior far exceeds our ability to define the biological response to rapid changes in physical habitat conditions.

Hydrologic considerations have a defined physical basis. The time it takes water to travel through the system often determines the range of applicability of steady-state models. The use of discrete steps in a steady-state flow model assumes instantaneous transmission of water across the model reaches and boundaries. That is, water beginning at the most upstream reach must exit the network within one time step for the model to be considered physically "valid." This does not mean that the model would not provide useful information if this rule were violated. But relying on such a model could be a mistake in a courtroom situation unless some routing algorithm, such as a diffusion analogy, is applied within the steady-state model. Remember that travel time is usually an exponential function of discharge. Depending on the size of your network, high flows may give rise to total travel times of less than one week through your network, whereas low flows may take more than a month.

Practical considerations are important for hydrologic models simply in terms of data availability. We mentioned earlier the consideration of data volume. Volume aside, it may not be possible to obtain the desired data for short time steps. The U.S. Geological Survey (USGS) reports only daily flow at most gages, but hourly data are available from district offices as strip chart or punched tape output. Use of such data will require additional data reduction costs.

Temperature modeling has the same basic considerations as hydrologic modeling. Travel time remains an important factor and data volume considerations are even more important. The steady-state temperature models we have been using have a minimum time step of one day, thus you are limited to predicting the daily minimum, average, or maximum water temperature. If you need finer time steps, a dynamic flow and temperature model or continuous site monitoring may be required. In either of these situations, the cost will rise significantly.

Matching Temporal Schemes of Models

Most existing models that deal with large river basins have a monthly time step. This is probably because a month is satisfactory for water management planning and any time step finer than that would escalate the data capture and processing costs beyond the benefits gained. It is difficult to find existing planning models capable of a finer time step. A notable exception among river basin models is HEC-5 (Hydrologic Engineering Center 1979). It contains options that allow use of daily time steps and selection among several algorithms, allowing approximate dynamic routing. HEC-5, however, requires extensive data, numerous runs for calibration, and a high level of expertise and experience.

Generic models, like HEC-5, may have an adjustable time step, but the costs involved must be considered before a decision on temporal resolution is made. It may be possible to mix time steps in order to mitigate costs. For example, April and May could be represented as months, but June and July as weeks. This might ensure that a particular life stage is covered more precisely.

In general, it is conceptually easier to link together models that share a common time step. Data may be linked more easily, using them may be less confusing, and final data presentation will probably go smoother. It is possible, however, to mix different models' time steps if necessary. For example, output from a daily model may be aggregated to a monthly basis to drive a monthly model. Rarely would you ever consider going in the other direction. Though a monthly model will provide average daily values, all true daily variability is masked.

In some situations, a weekly or monthly time step steady-state model will work well for all but critical periods. When this occurs, the use of a second, dynamic model for only the critical periods may provide needed resolution without the effort required for continuous dynamic modeling.

2.4 RESOURCE CONSIDERATIONS

Network habitat analysis is not a simple task. It demands much of an interdisciplinary team that must share a vision of where the effort should lead. Without that end point in mind, the tendency is for each subgroup to become isolated in its desire to make its own component work as well as possible. This is one key value of scoping. Periodic technical team meetings serve to keep the end point in focus.

Each network habitat analysis requires at least the following steps:

(1) data collection and transcription--literature, field, and lab;

(2) quality control--checking for consistency, accuracy, and completeness;

(3) model set-up--translating the characteristics of the system into the model's terms;

(4) model verification and validation--testing for reasonableness;

(5) model execution--running the programs to produce results;

(6) interpretation of results--learning about the system;

(7) display of results--making sense out of voluminous output; and

(8) communication of results--making decisions.

Steps 1 through 5 should take about half of your time and steps 6 through 8 should take the rest. About one-third of the field work should support step 5. The tendency to concentrate on steps 1 and 5, while ignoring steps 2, 3, and 4, greatly compromises one's ability to perform steps 6, 7, and 8. Your time should be budgeted to reverse this tendency.

Though each modeling effort is likely to be substantially different, we can give some general guidelines for what time one should expect to spend on several major components.

Table 1 displays three numbers for every discrete step we have identified for the various modeling efforts discussed in this document. These numbers should be interpreted as minimum, median, and maximum relative times consumed. Total "clock" time may be reduced by running some tasks concurrently. The low end can generally be characterized as follows: Data have already been assembled, checked, and documented and exist in machine-readable form; you are using an existing model with which you have had considerable experience; the situation you are modeling is not a radical departure from previous situations; you already know what the display products are; and much of the groundwork has already been done in the way of communication in previous, unchallenged efforts.

The median value represents an analysis effort where you are using a model with which you are familiar, on a new situation. Most of the data may be easily available out of a data base such as USGS's WASTSTOR, but some will require translation to the particular basin, and other data will require filling of missing values. Quality control is mostly a matter of checking for data outliers. Model setup is a challenge for the first time through, but it is a case handled well by the model you have chosen. Validation is not critical. The model results are straightforward, but packaging them for the audience you are trying to reach takes patience and thought. Much time is spent in coordination, explanation of processes, and trying slight variants of options just to satisfy individual's requests.

The highest time allotment reflects a much more open-ended situation. You must spend a lot of time actually collecting "raw" data, which will consume much of your resources and provide a challenge in quality control. No existing model is appropriate for this special case, so you must modify an existing model or build a new one. Therefore, verification and validation will require significant effort. Interpretation of model results is a challenge that requires significant time and effort. New display devices must be developed and the target audience is both hostile and unforgiving. For all of these reasons, we are unable to put a time cap on some of these steps.

In addition to the steps for the models discussed in this document, there are at least two other modeling efforts. The development, validation, and documentation required for both the species preference models and the microhabitat models may consume more time and effort than the rest of a network habitat analysis. Each has its own set of challenges. For example, if you are using an existing species preference model you may spend only one week on all steps combined; if you need to develop a model, you may be looking at a 5-year task. Similarly, the microhabitat modeling effort could range from 2

Table 1. Relative time requirements for each network modeling step. Values are given for a minimum (L) case, a median (M) case, and a maximum (H) case. Please see discussion in text.

Item	Flow model			Macrohabitat model			Habitat utilization model		
	L	M	H	L	M	H	L	M	H
Data collection	.5	20	100	3	12	150	0	1	8
Quality control	0	2	4	1	3	6	1	4	50
Model setup	.5	4	4	.5	8	Up[a]	1	8	50
Model validation	0	2	100	1	8	Up[a]	1	8	20
Model execution	.5	4	4	.5	3	8	1[b]	5[b]	8[b]
Interpretation of results	.5	2	4	.5	3	Up[a]	1	2	8
Display of results	1	2	8	1	2	8	1	4	Up[a]
Communication of results	2	6	Up[a]	3	6	Up[a]	2	4	Up[a]

[a] Up means we were unable to put a time limit on this element.

[b] Most steps in determining habitat availability have been automated as computer programs; however, the user is left the task of determining which units of available habitat should be summarized as utilized habitat. For example, the user would exclude available habitat in a tributary from total utilized habitat for a migratory species if there was a passage blockage.

weeks if you can use available data, to 2 years or more if there are numerous sites for which independent hydraulic studies must be launched.

One final note that pervades this whole discussion is that the level of effort on any of these tasks is highly dependent on the degree of accuracy defined as necessary to answer the questions at hand. In this context, we intend accuracy to mean accuracy in the "answers" of your modeling effort, as well as accuracy in spatial or temporal detail. Relative time, money, and manpower requirements are exponentially related to the level of accuracy required in an analysis of this sort.

3. COMPONENTS OF NETWORK HABITAT ANALYSIS

Network habitat analysis has eight components (Figure 4). The driving force of the network habitat analysis is the network flow model. The flow model accounts for all water flowing throughout the network in both space and time, schedules reservoir operations, accounts for all forms of water rights and delivery requirements, and records when and where violations to the rules are occurring. The flow model directly regulates both the microhabitat model and the macrohabitat model.

The macrohabitat model keeps track of water temperature, water quality (DO, pollutants, TDS [total dissolved solids], suspended solids), and even watershed equilibrium, sedimentation, and channel change. Temperature, for example, is a variable that may render whole tributaries or sections of stream unsuitable for a particular fish species. Contrast the macrohabitat model with the microhabitat model, which looks at the physical characteristics of small sections of a stream (depth, velocity, substrate, and cover) to determine the suitability of those small sections for the species under consideration. All of these specific elements are termed variables for our purposes because they may vary with the flow in the network or time of year. The macrohabitat and microhabitat models are the analysis components of the network analysis.

The species habitat criteria model is central to the analysis components. If we do not know how the species responds to macrohabitat or microhabitat variables, we cannot predict how changes in those variables will affect that species. We first must be able to translate flowing water regimes into their physical effects and then translate those effects into habitat values for each species. The species habitat criteria model is the mechanism that specifies the functional relationships between the limiting physical habitat variables and the preferences of the species for those variables.

If we know the flows, how those flows determine physical habitat, and how each species relates to physical habitat, we can estimate the amount of potential habitat in our network through space and time. We call this total available habitat because it may or may not be realized habitat. If a species cannot reach a particular location in the basin because of a stream blockage or other limiting factors, it will do no good to make habitat available in the inaccessable area. It is a necessary step in our analysis, however, to estimate the total available habitat, to respond to alternative management actions that may remove or create barriers to biological connectivity, i.e., the unimpeded movement of each species throughout the basin.

When we factor in the realities of species phenology, where each life stage is at which time of year, and physical or biological constraints, we are left with utilized habitat. This habitat is displayed in the network habitat utilization model and must be supported by field observations and documentation. As a practical matter, the difference between the utilization model and the habitat availability model is in name only. We made the distinction between the two to emphasize the idea of biological connectivity.

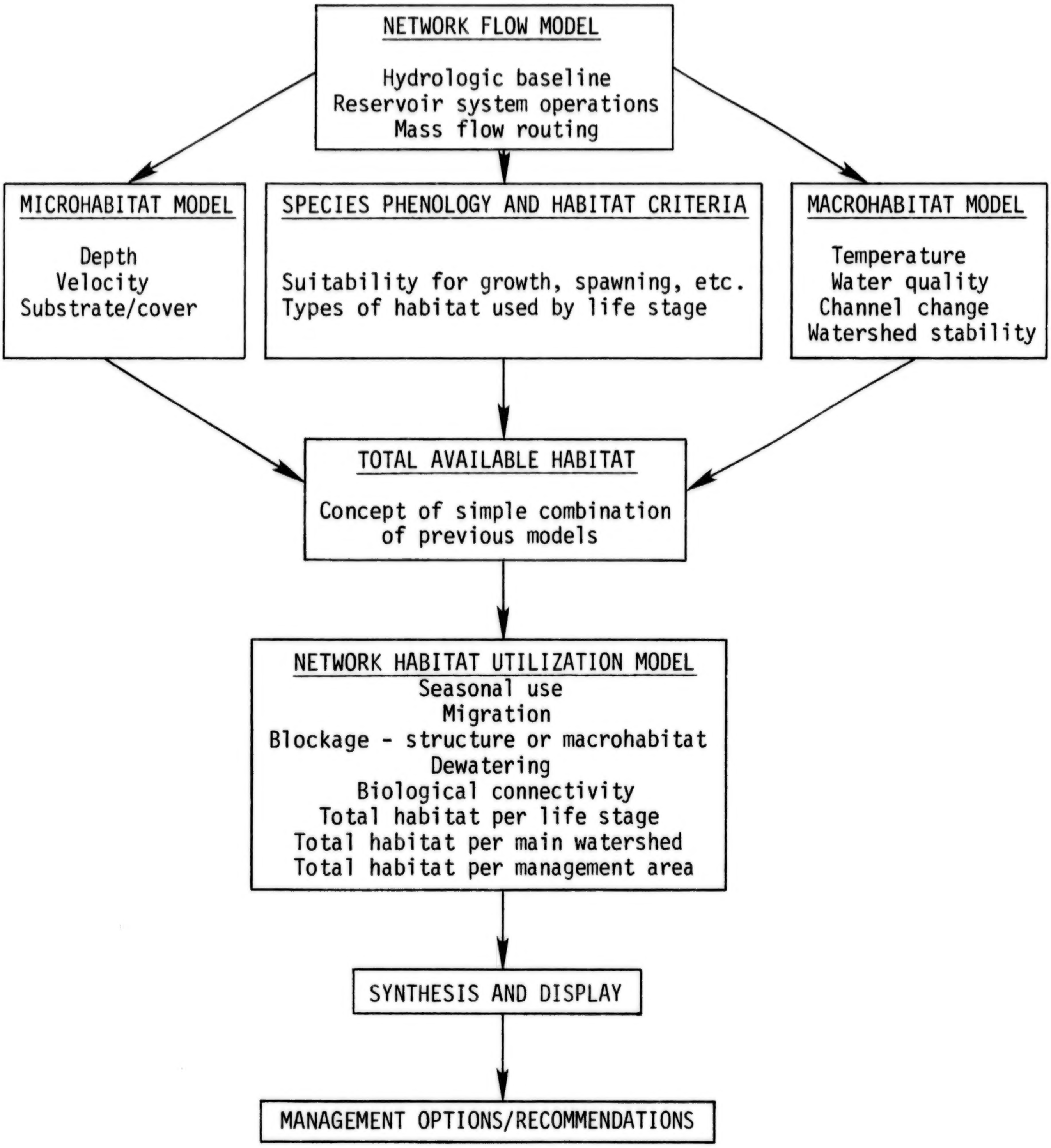

NETWORK FLOW MODEL
Hydrologic baseline
Reservoir system operations
Mass flow routing
MICROHABITAT MODEL
Depth
Velocity
Substrate/cover
SPECIES PHENOLOGY AND HABITAT CRITERIA
Suitability for growth, spawning, etc.
Types of habitat used by life stage
MACROHABITAT MODEL
Temperature
Water quality
Channel change
Watershed stability
TOTAL AVAILABLE HABITAT
Concept of simple combination of previous models
NETWORK HABITAT UTILIZATION MODEL
Seasonal use
Migration
Blockage - structure or macrohabitat
Dewatering
Biological connectivity
Total habitat per life stage
Total habitat per main watershed
Total habitat per management area
SYNTHESIS AND DISPLAY
MANAGEMENT OPTIONS/RECOMMENDATIONS

Figure 4. Components of network habitat analysis.

Implementing these models is only the first step in the analysis effort. We must then synthesize results from the often tremendous amounts of model output, display those results in meaningful and communicative ways, and translate the information into management recommendations. This part of the analysis often requires up to 50% of the project effort.

You have now been introduced to the major components of network habitat analysis. There is no hard and fast rule that you must deal with all of the components for every analysis. It is certainly legitimate to omit parts. For example, if water quality is not an issue, it may be perfectly acceptable to leave out that macrohabitat component. The choice of analysis components to apply to a particular problem should be part of the scoping effort.

We'll now look at each of the components of network habitat analysis in more detail. We need to learn what they consist of, what is required to make them work, what they will provide to other parts of the analysis, what their assumptions are, and what their limitations are. We will also tell you where you can learn more about each program or technique because we cannot cover the full range of material here. As we discuss each component, keep in mind the kinds of skills required to operate that component efficiently.

3.1 NETWORK FLOW MODELS

The first component of a basinwide model must be a description of the basin hydrology. Two aspects of this topic must be considered: (1) the basic hydrologic cycle (how the water gets there in the first place) and (2) man's alterations of stream flow through various management mechanisms. While models exist that translate precipitation into runoff and stream flow, water management entities usually rely on measured or synthesized stream gage records as the starting point in allocating the water resource. Analysis of gage data provides information on the likelihood of extreme events (floods, droughts) and the range of flows in the watershed, and their associated probability. This information gives a good indication of the risk associated with any given level of dependence on water supply in the basin. The variability of water supply is thus recognized, and most storage structures are designed and operated to minimize the risk of extreme events (Hall and Dracup 1970; Linsley et al. 1975).

Construction and operation of structures to alter the amount and timing of naturally occuring stream flows reflect man's influence on basin hydrology. Altered stream flows can be described by gage records in impacted areas, but evaluation of alternate management schemes is usually accomplished by the use of one or more computer models. These computer models are based on physical processes and decision criteria.

The physical processes modeled usually include conservation of mass and conservation of energy. The scale of such models usually precludes sufficiently precise description of hydraulic phenomena to require dealing with conservation of momentum.

The decision criteria portions of these models are as varied as the needs being met by the authors who have created them; however, some common characteristics do apply. The common areas often include storage evacuation for flood damage minimization, hedging (i.e., reducing the amount of water supplied when the reservoir is low to extend the potential time over which a reduced delivery of water may be sustained), maintenance of target minimum instream flows at points downstream of the reservoir, and some form of priority system so a selected balance between these objectives may be achieved within a model run. Usually this requires a tradeoff between project mandates, e.g., flood control requirements, water rights, water supply contracts, and instream flow needs. Some models of this genre can be operated to simulate any combination of priorities deemed reasonable by the model user, while others have a specific unalterable set of priorities "built in."

The models commonly used to handle the flow component of the network habitat analysis are steady-state reservoir operations and mass routing models. They are typically not "first-principle" models, which simulate watershed runoff events, evapo-transpiration, and groundwater recharge, though such detailed models do exist. The water-routing aspect of these models is conceptually simple in that they operate on an instantaneous bookkeeping method that monitors total volume of water moving through the network. No water is arbitrarily created or removed from the system. As shown in Figure 5, a means of accounting for each phenomenon, such as tributary inflow, return flow, groundwater inflow, and water diversion, is provided.

Figure 5 also lists rules that describe man's management of water. Over and above the simple mass balance structure of flow models, such operating rules determine the allocation of water within the modeled system. For example, we might add a rule that says that if a reservoir pool elevation goes above a certain level, we must begin to spill water in order to maintain a certain floodwater retention capacity. Or, we might impose a set of rules that simulates a complicated water rights arrangement in the basin with priority delivery requirements at specific times of the year. We might add capabilities to these models to allow us to monitor the electric power production potential of a reservoir operation. The ability to impose such rules gives this class of models its power as a tool for resource decision-makers.

Water systems management models have been used for many years by COE and BOR to facilitate both systems design and day-to-day operations of an integrated set of multipurpose reservoirs. Originally designed for rather narrowly focused purposes, such as flood control, their capabilities have grown to handle power generation, industrial and municipal demands, recreation, irrigation, and even other water uses, such as aquatic habitat preservation. Their logic is to meet clearly defined objectives at specified locations (called control points or nodes) for water storage and deliveries from storage over a period of years. It is this multiyear focus that makes these models complicated. Their job is to allow the water manager to be prepared for strings of wet or dry years, or whatever conditions might occur.

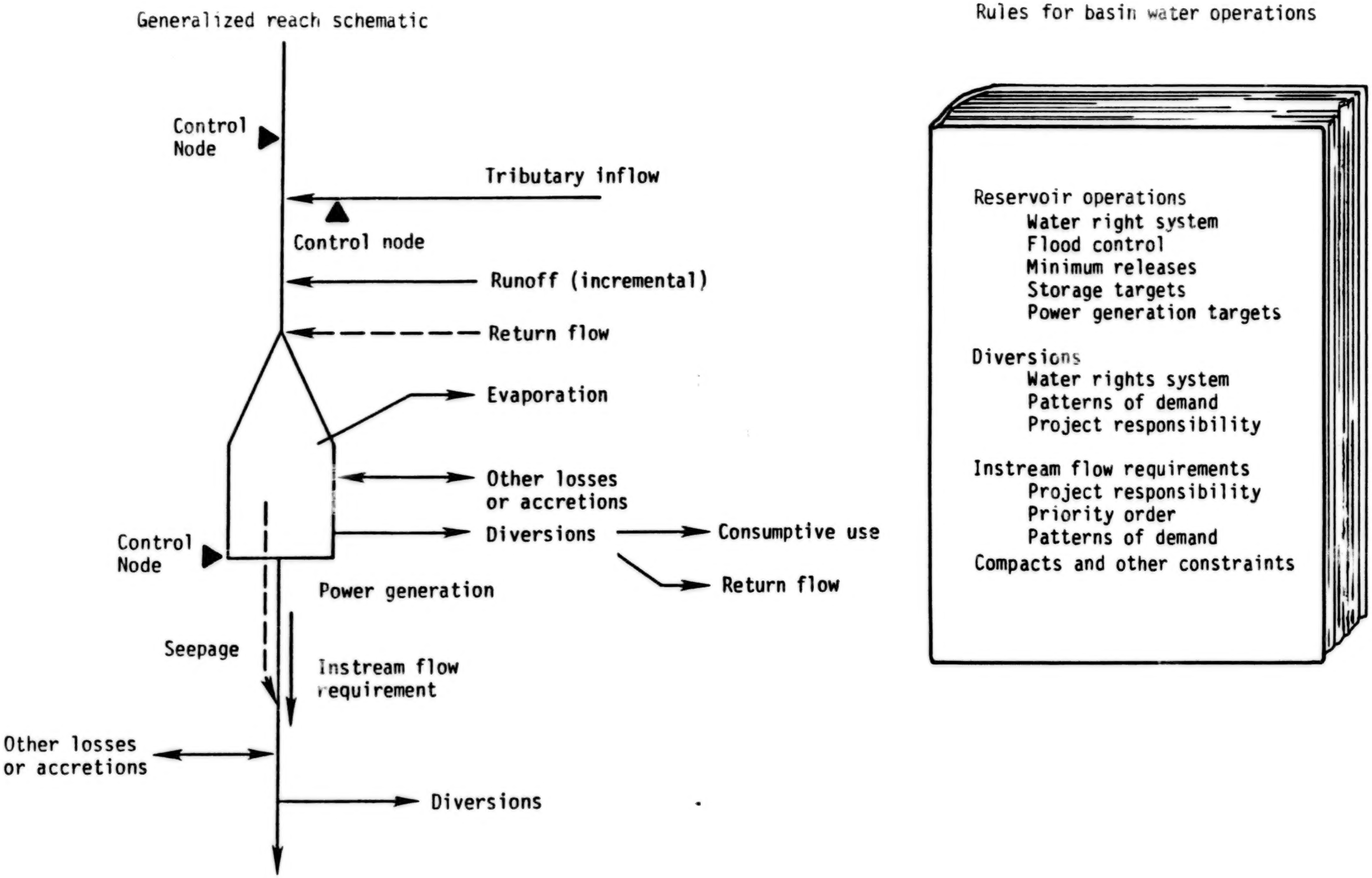


Figure 5. Major components of a network flow model.

The data requirements of network flow models are straightforward. A network must be delineated and known flows gathered for headwaters and intermediate points. Reservoir capacities must be known and their "rule curves" defined. These rule curves take the form of area, storage volume, elevation, and outlet works capacity relationships; decision rules for flood protection; satisfaction of water supply and demand; and hedging rules designed to minimize the risk of system failure. Diversion requirements must be clearly spelled out, with target flows and target storages for every time step in each kind of year (i.e., wet, dry, or normal). Applicable water rights priorities must be defined, and starting conditions must be known.

The models simulate the operation of the system under different water supply and management scenarios. Some models allow the path taken by the water to be externally defined by only the user-supplied data, while others are "hard wired," that is, the programs can only be applied to a particular streamflow network or basin.

The output from these models generally consists of tables organized by node and time. These tables usually contain predicted flows in the streams at each node, the amounts of water stored in the reservoirs, and summaries of the success or failure of meeting the delivery requirements or other operating goals. This information is carried to other components of a network habitat analysis.

Most existing stream network flow models assume a steady-state and therefore represent only average conditions over a specified time step; usually one month. Weekly time step models, however, may be appropriate for small networks. Daily time step models, which may be appropriate for dynamic flow effects, are also used where conditions warrant.

One typically must simplify the whole spectrum of rules and still capture the essence of system operation. Often, these rules are poorly defined or only minimally followed in actual day-to-day operations. Because these models are not first-principle watershed models, they cannot be used to extend flow records in a poorly gaged stream. Other methods of hydrologic analysis must be applied to this problem (consult a professional hydrologist). Also, there are practical limitations on the number of streams, reservoirs, and rules that can be handled at any one time.

At this point a cautionary note regarding costs seems appropriate. The demands placed on the user in terms of time and expertise required to successfully apply most stream network flow models increase substantially with the need to synthesize base data (due to lack of available data), the size and complexity of the network, and the intensity of the system management. Large stream systems, or systems in which great precision in model representation and actual management are required, will be very costly to describe with a model. Costs in terms of many tens of man years and millions of dollars for the modeling effort alone are not uncommon.

Generalized network flow models that might be applied are HYDROSS, HEC-3, and HEC-5. HYDROSS was developed by BOR in Billings, Montana. It is a monthly time step, steady-state model that utilizes a generic, data-defined network.

No optimization of objectives is performed. This model was recently (fall 1985) being revised by BOR and program linkages have been developed by the Instream Flow Group for extracting flows to be used by other components of network habitat analysis. For example, flows resulting from HYDROSS can be used to drive the Instream Water Temperature Model (IWTM).

HEC-3 is similar to HYDROSS in that it uses a data-defined network scheme and monthly time step. It includes more "hedging" rule capability and tends to emphasize flood control management more than water supply.

HEC-5 incorporates the concepts of HEC-3 and extends them to weekly or daily time steps. Many more reservoir operation options are provided and more information can be incorporated regarding channel capacity and flow routing (not just bookkeeping). HEC-5 also has some capability to produce analytical optimization of operations using linear programming.

As of this writing, linkages between HYDROSS and the network habitat analysis have been developed (see Appendices A and B). Linkages between the HEC models or other flow management models and the network habitat analysis have not been written, although they could be created as the need arises. This linkage programming must be considered as part of a particular network analysis and funded as part of that network study.

Earlier, in the "considerations" section, we noted the likely existence of locally accepted system flow models in many areas of the country. Such models certainly number in the hundreds, perhaps in the thousands. The same principle components are required for all such models. Their application in the network habitat context will require writing of interface programs and ingenuity in interpretation.

3.2 SPECIES PHENOLOGY AND HABITAT CRITERIA

To evaluate the consequences of alternative water management scenarios, the first need is to know how those scenarios affect the species under consideration. In most cases, however, a change in flow pattern of a water management scenario does not by itself directly affect any species. The exceptions are typically the inundation of free-flowing water by a reservoir or the inadvertent introduction of exotic species due to watershed interconnections. Changes in the amount or timing of flow affect target species through intermediate variables. These variables are most commonly considered to be the physical microhabitat parameters of depth, velocity, and substrate/cover, as well as the macrohabitat parameters of water quality (e.g., DO, salinity) and temperature (Bovee 1982). These intermediate variables appear to have more easily measurable influences on aquatic species than does flow alone. The assumption is that there is a direct, though unspecified, correlation between the habitat variables and the suitability for certain life functions. As stated earlier, just because the habitat is suitable does not mean that it is fully utilized by the species. This is particularly important when considering instantaneous measurements of the habitat without knowledge of prior events that may have depressed a given population.

Thus, flows resulting from a water management alternative can be translated into corresponding changes in microhabitat and macrohabitat variables. What remains is to further translate the resulting habitat variables into meaningful measures of the actual suitability to the species or life stage under consideration.

Methods have been devised to convert the micro- and macrohabitat measurements into an index of the total amount of habitat available for any aquatic species. These methods are beyond the scope of this paper. Bovee (1986) discusses the assumptions, development, and testing of species habitat criteria in detail. These criteria will subsequently be used during the process of microhabitat simulation and in the habitat utilization model, both described later in this document. Automated procedures have been developed in microhabitat simulation to incorporate a wide variety of habitat criteria. Many criteria uniquely applicable to networks would be factored in at the habitat utilization step, however, and are not automated at this point.

3.3 MICROHABITAT SIMULATION MODELS

Given criteria that describe how a particular species or life stage responds to macrohabitat and microhabitat variables, we must be able to predict how a water management scenario affects those variables. The microhabitat variables are handled by commonly available and well-known hydraulic simulation models. These models are capable of predicting the depth and velocity components for small parts (cells) of specific stream reaches under unobserved flow regimes (Bovee and Milhous 1978; Milhous et al. 1981). Inputs to these models are field measurements taken at representative stream transects. Typically these measurements consist of not only depth and velocity data, but also the cover/substrate index for each small cell.

These models are then used to predict the habitat variables for each cell over a whole range of possible flows through the stream reach under study. By knowing the depth, velocity, and substrate/cover for each flow, we can estimate the habitat available for the target species since we also know the relative suitability of these variables for that species. We can go a step further and develop what is called a microhabitat vs. flow curve that depicts the weighted usable area per unit length of stream available for the species at each simulated flow (Figure 6).

Examples of models that will perform these kinds of computations are IFG-4 and the Water Surface Profile (WSP) model. These models, both components of the Physical Habitat Simulation System (PHABSIM), are documented in Instream Flow Information Paper No. 5 (Bovee 1978) and IFIP No. 11 (Milhous 1984). Simpler methods, such as the wetted perimeter method, are also used by resource agencies. Wesche and Rehard (1980) present a comparative survey of several such methods.

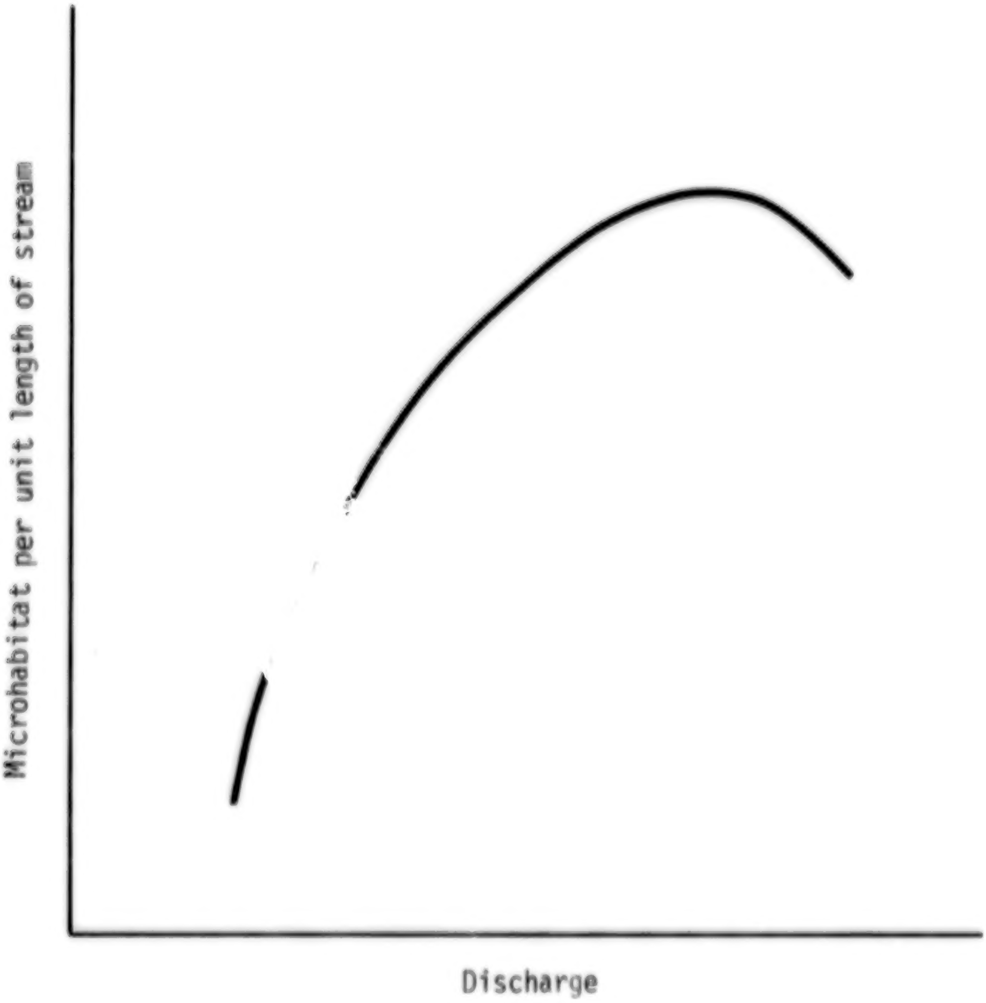


Figure 6. Typical curve depicting microhabitat availability as a function of stream discharge. One such relationship should be available for each life stage at each geographic location of interest.

3.4 MACROHABITAT SIMULATION MODELS

Just as we needed a way to determine the microhabitat response from alternative flow scenarios, we also need to be able to predict the macrohabitat response. The relevant macrohabitat variables are usually the water quality components: dissolved oxygen, biological oxygen demand, total dissolved solids, other ionic constituents, sedimentation, and pollutants. In addition, water temperature is one component that has received much attention, largely because it has important direct biological effects and because it affects other water quality components.

Because most of these water quality components are either conservative, i.e., do not dissipate with time, or directly a function of flow, the macrohabitat models are typically tied directly to, or form a subsystem of, a flow model. Therefore, like a flow model, these models often have a network layout and handle flow on a mass balance basis. In addition to knowing the headwater flows, however, we must also know the other inputs to the system--contaminant input loads, process rates, weather data (especially air temperature), and channel characteristics such as top width, slope, and stream shading.

The output from these models is also similar to network flow models in that we are given "read outs" of temperature or water quality through space and time for the entire network. Typically, the outputs are in mean and/or extreme values for each time step and appear in tables or graphs. In addition to predicting the macrohabitat values for individual geographic nodes, the models may also depict a gradient of specific variables proceeding downstream. Thus, lengths of stream having either suitable or unsuitable macrohabitat conditions may also be an output from these models.

Models of macrohabitat variables have the same assumptions and limitations as the network flow models discussed earlier. Examples of such models include two developed by the Instream Flow Group: the Stream System Assessment Model, SSAM-IV (Grenney 1981), and the Instream Water Temperature Model (Theurer 1984; often referred to as SNTEMP for Stream Network Temperature Model). Several other such models have been developed by the Corps of Engineers and the Environmental Protection Agency. Species responses to macrohabitat variables are included as part of the stream network habitat analysis tools described later.

The SNTEMP model provides very accurate predictions of mean and maximum water temperatures. It is a data intensive model, but most of the data are relatively easy to gather from available sources. SNTEMP handles only the free-flowing sections of the stream; no reservoir temperature simulations are included. SNTEMP is not a hydrology model; all flows must be supplied and are assumed to be correct. The minimum time step is one day, though most applications to date have been either weekly or monthly. Program linkages (see Appendices) have been developed by the Instream Flow Group such that the hydrologic input to SNTEMP can be supplied by the HYDROSS model. Similarly, linkages have been developed so that the output from SNTEMP can be used as input to network habitat models. (See Theurer (1984) for a more detailed description of the SNTEMP model.)

HEC-5Q is a model developed by the Hydrologic Engineering Center of the Corps of Engineers that combines reservoir operations and water quality. Temperatures are also simulated. HEC-5Q will adjust reservoir operations to meet user-supplied water quality targets if feasible. Multilevel dam outlets can also be manipulated to meet water quality constraints. Because HEC-5Q is so comprehensive, it is also one of the most complicated models to setup and run. It is expensive and requires a significant amount of computing power to execute successfully. (See Hydrologic Engineering Center (1984) for a more detailed description of this model.)

There are also models devoted exclusively to the modeling of reservoir water quality. CE-QUAL II and CE-THERM are two models developed by the COE for such purposes. CE-THERM is a subset of CE-QUALII. These models are one-dimensional representations of reservoirs and are designed to predict the quality or temperature of the reservoir's outflow. One-dimensional means that the longitudinal gradient of the reservoir is not directly considered in the simulation. CE-THERM would be a nice complement to the SNTEMP model if a linkage were developed between them. This would involve the SNTEMP simulating stream temperatures up to a reservoir, CE-THERM simulating the resultant discharge temperature, and SNTEMP using that discharge temperature in continuing to simulate downstream temperatures. (See Corps of Engineers (1982) for a more detailed description of these COE models.)

The most important assumption of macrohabitat simulation in flowing streams is that water quality and temperature are well-mixed across the stream channel and described in the linear dimension only. This assumption is generally violated in confluence areas. If a reliable simulation of confluence conditions is needed, a model suited to description of mixing dynamics must be applied, calibrated, and validated to that localized area.

3.5. CONCEPT OF TOTAL AVAILABLE HABITAT

Referring back to Figure 4, after flow in the network has been described, the total potential microhabitat and macrohabitat available for each management alternative can be predicted. The total network habitat for all sites and all life stages is obtained by summation. Habitat value for species X is the value at site one, plus the value at site two, etc. There are programs in the IFG library that do this simple summing. But, is summing the appropriate method?

A simple summation of habitat is only potentially available habitat, because it may not actually be used by the target species. There are several reasons for this. First, many species have distinct life stages through which there is an orderly and predictable progression, e.g., fry, juvenile, adult, spawning. Not every life stage, however, may exist at all times of the year. It is also important to ask where each life stage (that does exist at the appropriate time) would be found in the network. Many species are either actively or passively migratory and will seek certain areas at different times of the year. Anadromous species may move to or from ocean environments; the eggs or fry of many species may drift with the current.

In addition, we need to ask the important questions about biological connectivity. Can migration or movement actually take place? Is there a barrier of some sort that precludes migration either permanently or temporarily? Permanent barriers, such as dams, weirs, or waterfalls, are relatively easy to handle. Temporary barriers may consist of high velocity narrows or falls at certain times of particular years or water quality barriers (e.g., temperature) through which a species cannot easily pass. Changes in water quality could also be a barrier to anadromous species that are seeking their streams of origin.

Last, it may be important to determine whether the appropriate life requisites for progression of one life stage to the next have been met. For example, if there have not been enough degree-days for gonad development in the months prior to spawning, spawning may not be successful, even if all other conditions at the time are optimum. Therefore, the viability of one life stage is essentially a function of the preceding stages--the failure of any may break a fragile biological chain.

Thus, total utilized habitat does not necessarily equal total available habitat. We want to partition utilized habitat from available habitat for the above stated reasons as well as others. Potential habitat per se is not really a model. It is rather a necessary stepping stone on the path towards calculating total habitat availability. What does this tell us? We must at this point review each individual model, asking if it is the best we can do within the constraints of time, money, and manpower. We must also make sure that the ways we intend to link the models ensure the best fit possible. The combination of models must join together like building blocks. If we can accept the parts at this point in the process, it will be easier to accept the final results. There is no easy or automatic way, unfortunately, of checking the validity of the final product.

3.6 NETWORK HABITAT UTILIZATION

We have seen why the simple summation of potential habitat is not sufficient to describe total usable habitat. We have looked at the major considerations involved in distinguishing the potential from the utilized habitat. In an effort to be helpful with the task of habitat evaluation, we provide a checklist of species requirements to be completed prior to beginning a network habitat analysis.

The items contained in the checklist represent the most common biological considerations likely to be encountered in this type of analysis. These individual biological factors should be documented in the study plan. Those that are felt to be important should be operationally defined with specific and measurable units as appropriate.

1. Species phenology

   - what species/life stages are important
   - temporal distribution of each life stage (and what time steps these correspond to)
   - spatial distribution of each life stage
   - where would it be found if it could get there (potential habitat)
   - life stage interdependencies (i.e., must have successful spawning to have egg incubation)

2. Biological connectivity (space)

   - areas of dewatering or high flows (velocity barriers)
   - structural blockages (dams, weirs, waterfalls)
   - macrohabitat blockages (temperature, DO)

3. Biological connectivity (time)

   - temporal accumulation of life requisites (temperature, degree-days, extended growth conditions)
   - timing of certain threshold temperatures (e.g., water temperatures must reach X degrees prior to spawning)
   - peak flow timing (i.e., life stage dependent on either peak flow events, such as channel maintenance, or timing, e.g., requires descending limb of hydrograph flows)

4. Habitat stability

   - avoidance of rapidly fluctuating flows (e.g., flows swinging from one regime to another and back even though each might provide the same habitat value)

5. Changing community composition

   - regime management that favors certain species over others
   - channel change
   - introduction of exotics
   - watershed disequilibrium
   - streamside changes (riparian vegetation)

6. Others

   - recreation
   - access by public
   - pollution

As you can see, some of these items are straightforward and some are complex to the point of having no definitive answers. Some are addressed or enabled by using existing software and are illustrated in Section 5, but many are not. All we can do is to try to avoid being trapped by unexpected consequences that we should have foreseen. We would not be conducting an analysis unless there is a proposed change in the status quo of the system. Any change can lead to unanticipated results, and we should try to be as well prepared as possible.

A basinwide network habitat analysis model describes the habitat response to the effects of a particular management scenario. This is accomplished by evaluating the habitat components in the following order:

1. A management alternative is generated using a basin operation model that results in flows throughout the network over a planning horizon time frame (typically 50 years or more).
2. Microhabitat is evaluated for relatively short reaches that represent the entire range of the species of interest within the network, resulting in habitat-flow relationships for the entire basin, the length of stream represented by each, and the season and specific time steps to which they apply.
3. Macrohabitat is evaluated to determine the usability of the microhabitat in each reach.
4. Passage is evaluated at each potential blockage site and habitat elements are removed from consideration upstream of the actual blockage.
5. The product of microhabitat value times representative reach length times macrohabitat suitability (0 to 1) is summed across the basin or subbasins as appropriate to the species being studied.
6. The total habitat sum is computed for each time period (e.g., month, week, or day) in the planning horizon.
7. The resulting time series of habitat values are evaluated for frequency of extreme lows and duration of chronic conditions using such tools as the time-duration or exceedance plot (Viessman et al. 1977) borrowed from hydrology. Other indicators of system performance may also be needed for a particular problem. For example, number of consecutive years without adequate spawning, accumulation of degree days for maturation of gonads, or number of years with sudden drops in habitat between time periods.

The most critical model components in network habitat analysis are the feedback mechanisms. By feedback, we mean the model implementation of a management option that you design to show an improvement in the overall habitat response to a previously explored management option. In other words, one first simulates the habitat response of one proposal and then alters that proposal (usually slightly) in an attempt to improve the habitat response. Because the previously mentioned parts are indeed separate models it is not likely to be easy (or perhaps even desirable) to attempt some form of automated feedback. Rather it is suggested that the user provide the feedback mechanisms by interpreting the results of one management scenario followed by suggesting modifications that would improve habitat either at various times or places, or both. This feedback often takes the form of flow recommendations for various locations within the basin for various times of the year. These recommendations should also consider some form of adjustment for high, low, and average conditions of water supply and windows of operation to be most applicable.

It is important to stop here and reflect on the ground we have covered. We have been linking models together, each of which is based on some assumptions, and hence each of which undoubtedly contains some error.

Elementary probability theory would lead us to the conclusion that the chances of being "right" about our predictions of habitat follow in a multiplicative decline through each preceding model. That is, if we have succeeded in describing the flows accurately to within 90%, the species habitat preferences to within 90%, the microhabitat and macrohabitats to within 90% each, we may be down to the 66% accuracy level for the analysis as a whole, at least in theory.

4. SYNTHESIS AND COMMUNICATION

So now you have assembled a set of models for your particular problem. You've spent a tremendous amount of time and energy gathering data, making models run, fixing last minute details and pouring over model runs to make sure that everything is acceptable. What now? The goal of all of the energy spent up to this point still lies ahead. You must synthesize the results of your analysis in meaningful ways and communicate the information to a variety of audiences. You must make sure that your audiences fully understand:

(1) what has been done in the analysis with accompanying assumptions and limitations,

(2) what are the results of each carefully selected alternative,

(3) how you think those results should be evaluated with respect to the species or system goals,

(4) what the conclusions and recommendations are and how to best implement those recommendations, and

(5) how to monitor the postproject behavior of the system.

We suggest that up to 50% of your total time must be devoted to communicating these five items. If you have done your job properly, you have been anticipating the communication of results all along, so the job will not be too formidable.

The communication process begins during the planning and scoping process. At that time you should make others aware of the project plans to ensure that the organization is committed to providing necessary resources to address the problem. The communication process continues when you ensure that all of the staff have agreed on objectives prior to commencement of the analysis. This coordination helps to prevent internal conflicts from diluting the effects of project evaluation. Remember that communication is a two-way street. Put your ideas at risk; be open to criticism. No one likes to have fault found with his ideas, but feedback may contribute to the analysis by posing valuable hypotheses that may be tested or by defining the analytical limits of the models used.

We will now look at a variety of tools (methodologies) that can be used to address these five points.

4.1 TOOLS FOR "WHAT HAS BEEN DONE"

It is important that your audience understand your analyses. Understanding best takes place if your audience can relate your activities to their particular realm of experience.

Narrative descriptions or documentation are generally the primary means of communication. Careful documentation of progress on the project, and the assumptions and limitations you have made (and the rationale for those assumptions), is critical. Audiences will also want to study parts of the analyses according to their particular fields of interest. Engineers may examine portions of computer programs to make sure that well-recognized formulae are used correctly, or they may require detailed explanations of algorithms used such as the "step backwater" approach to hydraulic modeling.

Biologists will also be interested in various aspects of the analyses, such as the location of habitat inventory transects, or how accurate current meters are in eddy pools. They may want to know how you can justify extrapolation of one 60-yard reach of river into 60 miles of riverine habitat.

You should be prepared to meet each person on his own level, using different explanatory techniques as necessary. Holling (1978) presents a good discussion of explanatory presentations. As a corollary, you should be prepared to discuss when your model is no longer appropriate for some situations. Too often the tendency is to stretch the applicability too far.

4.2 TOOLS FOR "GENERATION OF ALTERNATIVES"

The development of alternatives is an important part of the synthesis process. Some alternatives are likely to be mandated by water development agencies, Congress, or previously drafted environmental impact statements. We will not discuss those alternatives to which you must respond. Instead we'll concentrate on those alternatives you should develop as part of a comprehensive analysis.

The development of reasonable alternatives is important for the good of the resource and the long-term economic gains of the project sponsor. A reasonable range of alternatives must be examined to develop a perspective from which to judge the merits of the mandated alternatives. The best alternatives are those that benefit all concerned. Do not get trapped into choosing the "best" from a given set of poor alternatives! Remember that the ultimate use of a basin simulation is to develop alternative schemes that satisfy the major concerns of many interest groups. Ideally, one or more of these alternatives can form the basis of a negotiated management solution.

Although not every conceivable alternative can be explored, you should think through a "worst case" scenario. Here we mean "worst" from your point of view. Scenarios are "hypothetical sequences of events constructed for the purpose of focusing attention on causal processes and decision points" (Kahn 1967). The purpose of a scenario is to display, in a dramatic and persuasive fashion, a number of possibilities for the future. They are not predictive, but rather exploratory.

In the worst case scenario, it is appropriate to try to think of the worst set of circumstances that might reasonably be expected to occur. One reason to develop a worst case scenario is because average conditions developed by your models (especially monthly time step models) do not fully reflect extreme events, which will occur. Simulating extreme events compensates for the otherwise typically conservative modeling approaches. For example, if the mean monthly flow through a model node is 500 cfs, but flood flows of 5000 cfs can occur during that time step, it may be instructive to investigate the possible effects of a 5000 cfs flow.

The absolute worst case will probably never happen, but by examining the possibilities, you may be able to identify extreme events or combinations of events that should be avoided at all costs. These "catastrophic loss" situations may be referred to in your recommendations as circumstances to avoid. It is even more useful if you can indicate the operating rules that should become dominant in those circumstances. For example, suppose the design criteria for a set of reservoirs allowed for a 5-year string of low water. You have determined that there is a high probability that at least one of those five years will be extreme in a meteorological sense, affecting water temperatures adversely. In such a case, you would want to have a contingency plan or mitigation actions ready.

Depending on the needs of the species being evaluated, extreme conditions can potentially be best or worst cases. Figure 7 shows a matrix of flow and temperature events. Specified flow exceedance values have long been used by hydrologists to define water supply contingencies. A flow exceedence value specifies the probability of the given flow being exceeded. For example, a 20% exceedence flow is equalled or exceeded by only 20% of the other flows of record. This matrix simply extends the logic a bit further. On one axis is the typical categorization of wet, normal, and dry years represented by 20%, 50%, and 80%, or whatever is appropriate for your case, flow exceedance levels. The other axis categorizes the water temperature years or critical temperature period within years as hot, mild, and cold, again using 20%, 50%, and 80% air temperature exceedence levels. (We chose to use air temperature instead of water temperature because air temperature is the single most important factor in determining water temperature and is much more easily obtained.) Thus, nine combinations of conditions may be explored and reasonably be expected to capture the range of extreme conditions that may occur.

This matrix should not be taken to imply that there is an equal probability that a given year will be in one of the nine boxes. For example, if we are concerned with the Upper Colorado River Basin, we would expect many more hot-dry years than we would hot-wet years, since the basin is both tepid and arid. The actual probabilities for each compartment may be developed, and may be of use in identifying low probability events for your worst case scenario evaluation. This matrix, then, allows you to compute the relative probability of each combination of factors on the axes. For example, if you had 100-years of data which you categorized for each axis, you might have 30 fall in the hot-dry category and none in the hot-wet category. Also, the contents of each box need not be years; instead they may be strings of years, which would enable the evaluation of reservoir carry-over conditions. When a string of years is used, model runs to develop a habitat index for the multi-

AIR TEMPERATURE
(resulting from meteorological events)

		HOT 20% exceedence level	MILD 50% exceedence level	COLD 80% exceedence level
FLOW	WET - 20% exceedence level	Low probability		Medium probability
	NORMAL - 50% exceedence level		High probability	
	DRY - 80% exceedence level	Medium probability		Low probability

Figure 7. Scenario generation matrix showing relative probability of occurrence.

year condition (such as the lowest habitat value in all years of the string) will be required.

The tools discussed to this point consist entirely of simulation models. Simulation models have the advantage of describing a system in a form that can be manipulated to determine potential results of various management schemes, without the cost of actually trying each approach in reality. Gaming with these models will allow you to attempt to maximize the amount of habitat under the constraints of water availability. Any optimization that is obtained is derived solely from the insight of the analysis to which the model is applied. There is another class of tools that can be used to go beyond simulation to optimization.

The field of operations research provides a wide variety of tools for analytically determining a quantitative optimum within limiting constraints. Examples would include linear and goal programming, input/output matrices, and graphical techniques. These tools are commonly used in the areas of business, economics, and engineering, where the emphasis is on minimizing the cost of a given pursuit.

In water resource management, optimization models have been applied to the traditional water uses. By assigning dollar values to the benefit of applying a unit of water to a given use, these methods have been used to determine the mix of water uses that provide the maximum benefit within the operational constraints of the system being studied (James 1971). These techniques could be applied to management of water resources considering habitat in several ways.

To take advantage of these tools, some means of translating habitat requirements into units that can be traded against other uses is necessary. The following two approaches are suggested as examples of how this may be accomplished. Flow requirements for habitat can be expressed as "windows," i.e., flow regimes bounded by upper and lower values indicating the limits of acceptable habitat. These limits can be established as constraints to an optimization model. The model would then be used to maximize the "benefits" from water for the traditional uses, subject to providing instream flows that provided the bounded amounts of habitat. These boundaries could be established for a critical period or for the entire year. They could vary seasonally, monthly, or over any other time period relevant to the analysis.

Sale (1981) used a linear programming technique to operate a reservoir for the optimal provision of physical habitat in an Illinois river. His approach treated habitat as the objective of the operation and incorporated the other demands on the system as constraints. That is, given that a specified amount of water must be stored in a reservoir and diverted for water supply to a city, how can the remaining storage and release operation be adjusted to maximize the amount of habitat available to the species of concern. In a situation where a particular life stage of a particular species has greater importance than other life stages or species, the objective function (the formulation of those variables one wishes to maximize) can be weighted so that the reservoir operations favor that life stage when water shortage occurs.

This discussion has been included to give a brief idea of one optimization technique available. Most optimization tools require specialized training. The cost is often higher than simulation, which acts as a deterrent to use of optimization in low budget analyses. When the resource at risk is of high value or the opportunity exists to manage the water system to significantly improve the habitat conditions in a river system, however, use of these tools may be justified.

The result of generating alternatives is to provide you with additioal hypotheses to test with your models.

4.3 TOOLS FOR "EVALUATION OF ALTERNATIVES"

There are several tools (computer programs) that can aid in the evaluation of alternatives. The word evaluation implies quantification, but not all of the effects of any alternative can be quantified. There rarely is a "bottom line" figure on which you can depend. The actual "numbers" resulting from your analysis are best viewed as relative measures of system response rather than accurate values. We are in a better position to understand how the system functions, for example, than we are to predict that the temperature will be X degrees next January.

It usually takes the subjective integration of several factors, some of which may be intangible, to help you decide among a set of alternatives. You should carefully choose quantitative indicators of system performance prior to starting your analysis. These indicators are typically quantitative "read-outs" of the system's production of various factors: habitat areas, numbers of fish, power production, irrigation flows, satisfied water rights, fisherman use days, biomass, fisherman success ratios, micrograms per liter, and so forth. Tables and graphs of these system indicators may be assembled to show the system's behavior over time or space.

Usually it is too demanding of your audience to try to present both time and space for each species/life stage in one composite representation. An exception is the use of flow duration curves, which can be used for each location of interest. To look at a network as a whole, however, we need to aggregate geographic locations or develop other "whole system" indices.

The collection of programs provided in the Appendices serve to bridge the gap between flow and/or temperature models and habitat models that cover an interconnected river network. Each program in this series offers a mechanism for producing habitat or other summary over both time and space. The main features of the five programs are summarized here.

LNKQ2T is a program for linking the HYDROSS river network operations planning model to the Instream Water Temperature Model (SNTEMP). The linkage updates the temperature model's hydrology data file for use in "what if" type temperature evaluations of various water management scenarios that have been simulated using HYDROSS. The linkage does not eliminate the need for the user to have previously calibrated the temperature model to historic conditions, nor will it provide reservoir release temperatures for the alternative water management scenarios.

LNKQ2H is a program for converting the HYDROSS river network operations model's flows to habitat values over a network. This program will match the flows generated by HYDROSS with a habitat versus flow relationship (from PHABSIM or other source) for one or more life stages at one or more locations, to produce a networkwide habitat time series for each life stage. The time spans and time periods considered, locations to be summed, life stages to be included, and output formats generated can be selected.

LNKT2H is a program, similar to LNKQ2H, that links the output from the temperature model to produce habitat values. LNKT2H provides the same flexibility as LNKQ2H and provides additional capabilities as well. This program will factor into the habitat versus flow relationship a temperature suitability index for each life stage under consideration. Thus, a temperature-conditioned habitat time series can be created. Part of this linkage will also calculate the accumulation of degree-days over time at specific locations throughout the network. Great flexibility is provided in the definition and calculation of degree-days.

LNKG2H is similar to all of the above programs. Instead of utilizing the HYDROSS or SNTEMP models, however, this linkage uses a simple U.S. Geological Survey or Northwest Data Center flow time-series data file to generate a habitat time series. Like the above programs, flexibility is provided in deciding what to include in an analysis and what to omit. This program can also weight the habitat with information provided by an input file containing a temperature time series. This program, however, does not produce a degree-day time series.

LNKT2TS is a program to extract a temperature and flow time series from the output of the Instream Water Temperature Model. It will read the temperature model's output files and produce the requested time series files in whatever format desired. The same features of user-selected time periods and locations are provided.

Figure 8 illustrates the functions of the computer programs described.

4.4 TOOLS FOR "RECOMMENDATIONS"

The recommendation process brings all the expertise available to bear on the problem at hand. Not only are all previous actors involved, but the general public and sometimes the court system are now players as well. In this document, we will intermix the implementation and monitoring aspects of a project along with our discussion of recommendations, because a good set of recommendations will have thought the whole process through to its logical conclusion.

There are various tools that may be employed in the process of developing and implementing recommendations. These range from workshops and negotiating sessions to adversarial proceedings. Do not make the mistake of putting together a poor set of recommendations. After all, to be implemented, your recommendations must first be accepted. Let us spend some time looking at the different ways of coming up with a workable set of proposals.

Workshops are useful forums for getting most of the interested parties around a table, developing ideas, presenting findings, sharing expectations, and exploring feasable solutions. In fact, you may have used workshops early in the modeling process to scope the nature of the problem and to lay the groundwork for informing people of what was to be done. These workshops contribute to three levels of utility: conceptual, developmental, and output.

Conceptual utility describes the benefits derived from organizing ideas about how a complex system functions. Workshops held early in the process serve to establish interdisiplinary communication and offer a springboard for mutual understanding as the process matures to the point of recommendations.

Developmental utility describes the benefits associated with synthesis of data and construction of functional relationships from those data. Without background communication of this sort, from a workshop or otherwise, some parties asked to be supportive of your recommendations may view the process as a black box. The synthesis of data, identification of important functional

MAJOR DATA FLOWS COVERED BY NETWORK PROGRAMS

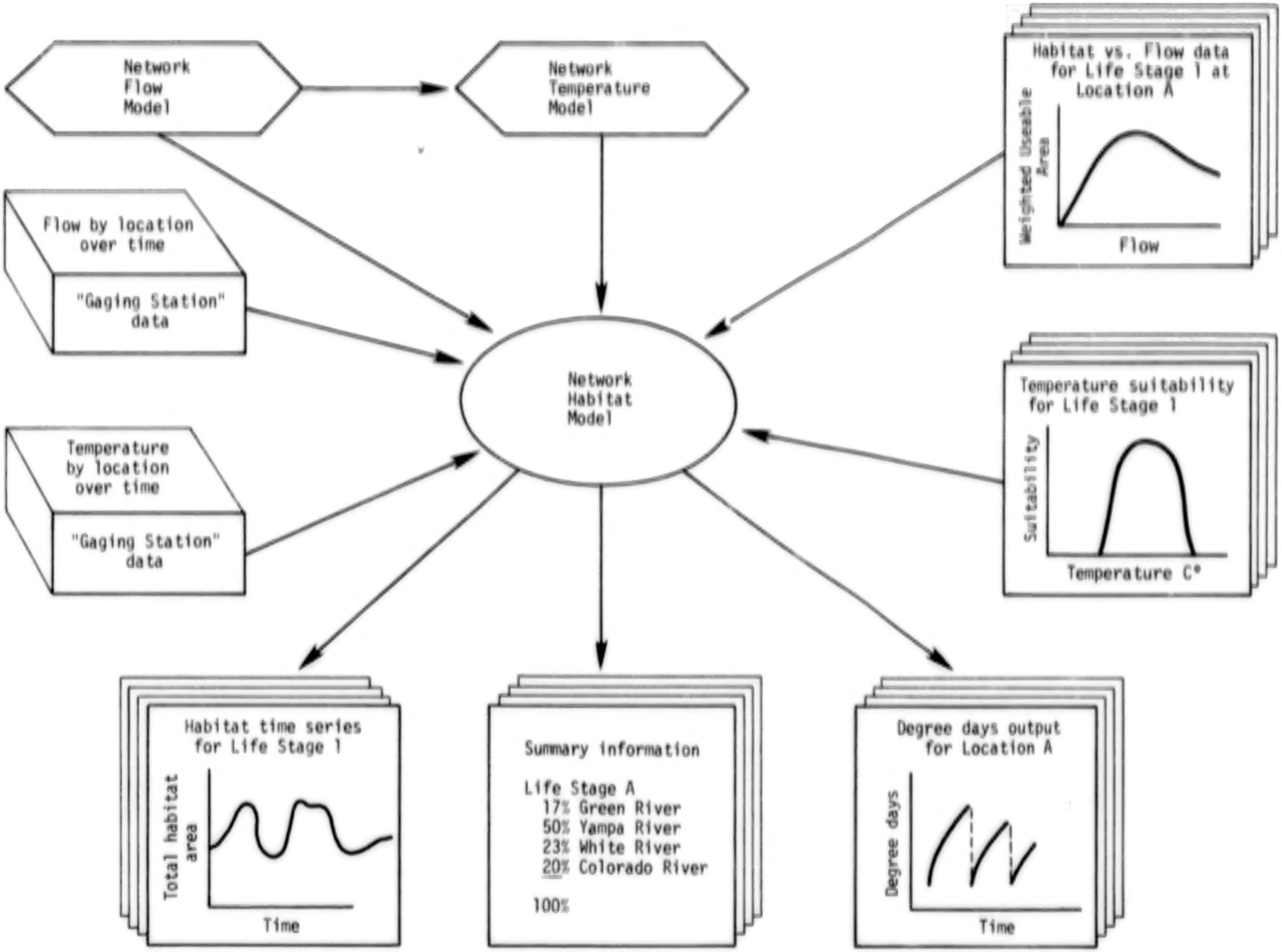


Figure 8. Computer program functions covered by documentation in the Appendices.

relationships, identification of data gaps, and demonstration of inconsistencies are the important elements of this step in the process.

Output utility refers to the benefits accruing from the examination of model results. This examination should result in either a sense that the models are credible enough to be used in applied management decisions, or to identify research priorities. Sometimes we fall short of a definitive slate of hard and fast recommendations; but when employed in an iterative fashion, with modeling results used to suggest experimental efforts and empirical results used to modify and improve model performance, modeling can eventually lead to output that has enough credibility to be useful in a quantitative, predictive way.

Public participation will usually be mandatory during several steps in the process of building recommendations. Since we are primarily interested in Federal and State actions, the Fish and Wildlife Service and the State fish and game agencies must identify the public interest. Public participation helps reduce the chance that Fish and Wildlife Service recommendations will be stalled or reversed by legal actions or political intervention. Public participation may often improve a set of recommendations because it may bring to the surface very real, if obscure, reasons that plans generated by "experts" might fail. Finally, public participation can "grease the skids" to move sound plans through the regulatory processes. The Fish and Wildlife Service has a Policy Statement and Guidelines for Public Participation (1981) that may serve as an aid in describing the minimum requirements and recommendations for public involvement.

The full scope of negotiation is a document in itself. In fact, the Instream Flow Group offers a course devoted entirely to negotiation and conflict resolution. In essence, the skill needed here is communication to further mutual understanding.

Should you find that negotiations have ceased and you end up in court, a different set of conditions will guide you. Again, the Instream Flow Group offers a course explaining the role of expert witnesses, attorneys, and the whole legal process in general. A document, called Guidelines for Preparing Expert Testimony In Water Management Decisions Related to Instream Flow Issues (Lamb and Sweetman 1979), is available. Should you believe that there is a high probability that your problem will end up in court, you should review this document; there are actions that should be taken early in the modeling process related to chain of custody of data and documentation of models that may prove to be important.

It is not possible to give explicit instructions on how to develop recommendations. We can, however, provide you with a list of physical and institutional considerations, as well as general strategic ones.

First, you should ask if your recommendations can be implemented physically. Is there enough water in the system to support your recommendations? Recommending a management scenario that results in a shortage of water may happen if you "picked the peak of the curve" without running the scenario through your models to observe the consequences. Irreparable damage can be done to you and your organization if you proceed down the path of maximizing everything from your perspective.

Second, you should ask if your recommendations can be implemented institutionally. We have mentioned water rights and interstate compacts before. You must test your recommendations against this template for feasibility. Some of your recommendations may, of course, be directed towards the modification of some kinds of contracts. But beware the legal tangles involved!

Third, you should be prepared to demonstrate that the aquatic system your recommendations are designed to protect is worth it in a socio-economic sense. Occasionally, as in the case of an existing legal mandate such as the Endangered Species Act, this may not be required. In the absence of a "legitimized value," your recommendations may face the acid test of their worth to society at large.

Fourth, and last, we can offer a group of strategies that make sense and have been demonstrated to have merit (Lindblom 1971). When possible, propose recommendations that are only incrementally different from existing policies. This strategy has the advantage of information being available on the suggested scenario's operations, and the increased probability of implementation. Design your recommendations such that they are reversible and allow you flexibility. Do not propose that your recommendations be carved in stone, but rather that they be tried and modified if shown to be unacceptable. Try to design recommendations such that you can learn from a mistake if one occurs.

Another important strategy is to be partisan. In most cases it will not be your responsibility to design recommendations to achieve the optimum for all parties. Look first to the aquatic system and try to propose the best for that system. It would be unwise, however, to ignore the broader value base involved, for you can use this information in your design and in negotiations.

A well-designed monitoring program goes hand-in-hand with a full-fledged set of recommendations. Monitoring is an area that has always taken a poorly deserved backseat in most natural resource situations. The reasons are obvious: there is usually a lack of preproject (baseline) studies, making evaluation difficult; follow-up studies may take a long time (10 to 15 years); time, money, and manpower must be budgeted in the face of other, pressing issues; cumulative impacts from multiple development actions may make single project impacts difficult to untangle. The development of a sound monitoring program should help to evaluate the efficiency, effectiveness, and adequacy of our recommendations. Efficiency refers to the overall cost/benefit of the recommended program. Effectiveness refers to whether or not the intended results were achieved. Adequacy refers to whether or not the recommendations were sufficient to ensure that our resource goals were met. In addition, a sound monitoring plan also serves to build institutional credibility (assuming the plan is successful) and is self-educating.

Once again, we cannot tell you exactly how to design a good monitoring program in this paper, but the following general advice should be considered. First, make sure that your goals for the resource are absolutely clear. If you are concerned with species management, you are limited to only a few resource goals (Figure 9): enhancement, reduction, preservation, restoration, stabilization, reduce losses, or replacement. Enhancement means that demand for the resource requires more of the resource in the future. Reduction means the need to reduce or check a nuisance condition. Preservation means the maintenance of the status quo. Restoration means that the resource is to be returned to some earlier, more satisfactory, condition. Stabilization means that the resource's condition can only be maintained at or near current, if somewhat unsatisfactory levels. Reduce losses means that you are attempting to curb the rate of deterioration. Replacement means that the resource is deteriorating such that it should either be established somewhere else (in kind) or that a different resource should be substituted or enhanced in its place (in value). The Fish and Wildlife Service's Mitigation Policy may be of some use in helping to establish your recommended goal for the resource (Department of the Interior 1981).

Once you have a clearly defined goal, the recommendations should all be directed towards supporting that goal. If permits are involved for a particular project, make sure that your recommendations are attached to the permit in a legally binding way. Develop quantitative criteria by which the progress towards your goal can be monitored. Allocate your resources to make the monitoring program a success. Since you expect to learn from your monitoring program, make sure that you have feedback to your recommendations such that they may be modified from what you learn. Couple your monitoring program with efforts to learn more about the system, for there were bound to be weaknesses in the modeling process.

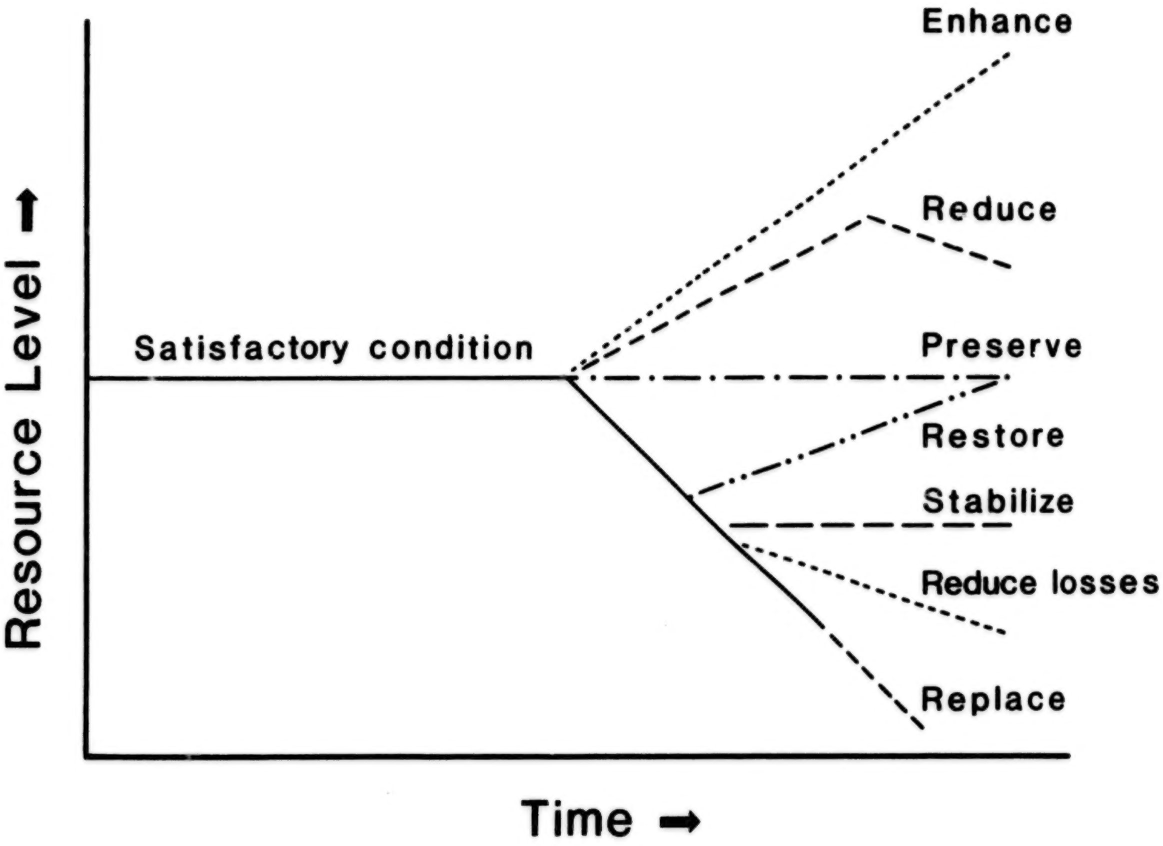


Figure 9. Generic resource goals.

5. AN EXAMPLE: THE DAVID RIVER BASIN

The following pages contain the description of baseline conditions and a proposed water development in a hypothetical river system. The example has been constructed from data obtained from several sources. Monthly flow and reservoir operation scenarios were generated using the HYDROSS model, and stream temperatures were generated using the SNTEMP model. Flow data were adapted from the sample data set supplied with HYDROSS by the Bureau of Reclamation, and weather data were taken from the National Weather Service station at Grand Junction, Colorado. The habitat and temperature response functions for "bravefish" were created for this problem. While these response functions do not represent a particular species, they are similar to the response functions one might expect for species found in large rivers in arid regions of North America.

5.1 SETTING: DAVID RIVER BASELINE CONDITIONS

Hydrologic Setting

The David River (Figure 10) drains a mountainous area in one of the Western States. Until recently the upper David River basin had not experienced a great deal of water development and as a result it flows in a nearly natural state. The old mining town of Goldville is located at the point where the David flows out of the rugged mountains into and the intermontane basin known as Alfalfa Park (km 118.5). Just above Goldville is a good reservoir site where a large granitic batholyth forms the eastern boundary of Alfalfa Park. A small diversion is taken from the river at Goldville for local pasture irrigation. All return flows from that diversion accrue back to the river above Tea Kettle Springs (km 88.5). This hot spring discharges at a constant rate of .8 cms (28 cfs) and a temperature of 60 °C. Below Tea Kettle Springs, the river flows through a major habitat area known as Flat Meadow. Below Flat Meadow the river is joined by its major upland tributary J. P. Creek.

The J. P. Creek basin is smaller and somewhat higher than the David River basin, above their confluence. J. P. Creek has thinner and poorer soils, resulting in a lower summer base flow. Hence, a relatively greater percentage of its annual flow is derived from spring snowmelt runoff.

Just below the confluence of the David River and J. P. Creek is one of the best available reservoir sites in the upper basin. This canyon, known as Blue Gorge, has steep walls of solid granite that would allow construction of a large reservoir.

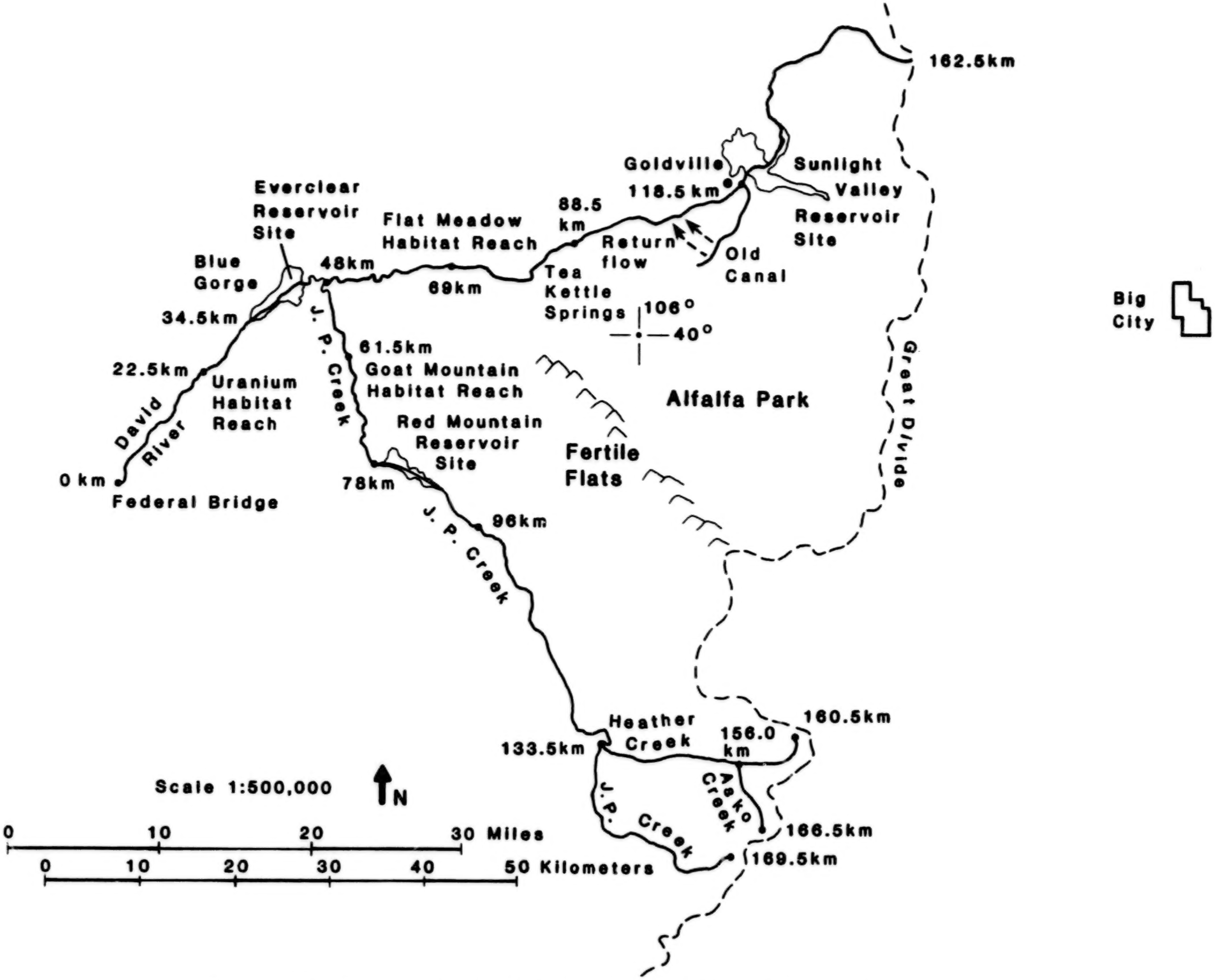


Figure 10. Map of David River basin showing location of three important habitat reaches and three possible reservoir locations.

A third habitat site is downstream of Blue Gorge near an area noted for its mineral deposits. This reach of the river is known locally as the Uranium Reach due to abundance of that mineral in the area.

The study area ends at Federal Bridge (km 0.0). Several water rights holders in the lower David River basin have very old water rights that require certain minimum flows to pass the bridge at various times during the year. These rights are most easily represented as a single requirement that varies with the seasons and between years. The volume of the delivery requirement reflects the aggregate water rights of those rights holders that are in priority in any given year (in dry years, less flow is needed, as the downstream junior rights holders are eliminated by the senior "old" Alfalfa Park rights holders).

The runoff in the basin is dominated by snowmelt. Due to the high altitude and latitude of the basin, the peak runoff usually occurs in June or July. This pattern, with high melt flows and a much lower summer base flow is typical of the central mountains of North America.

Six years of record are available for studies in this basin, calendar years 1980 through 1985. Though this short record is less than the minimum 10 years recommended for this kind of analysis, this period does encompass a range of annual water availability from very dry to very wet. Years 1980, 1981, and 1984 had approximately average annual runoff for the basin, 1982 and 1983 were dry and very dry, and 1985 was a particularly wet year (see Tables 2, 3 and 4).

The best potential reservoir locations in the basin are above Goldville and in Blue Gorge. Both sites are in bedrock gorges that could withstand the stress of a reservoir structure and the attendant water volume. The Goldville site could accommodate a reservoir as large as 200 KDAM3 (thousand cubic decameters) or 162 KAF (thousand acre feet). A 180 KDAM3 reservoir has been proposed for that site.

Baseline condition flows through the Flat Meadow and Goat Mountain habitat areas are summarized in Tables 3 and 4.

Institutional Setting

The appropriative doctrine is used to determine water rights in this State. Thus the concept of "first in time, first in right" applies. Under current (baseline) conditions, the water in the upper David River basin is not subject to particularly intense use. Even in dry years, the current users are able to draw all of the water their rights entitle them to. Some low priority users in the lower basin are not able to get all of the water they desire in dry years.

Summary

The upper David River basin has the potential to support several possible water developments. Under present conditions there is little need for intensive water management, other than the normal priority system. A great

Table 2. David River basin annual flow summary by HYDROSS control point.

Station number (based on USGS gage number)	Station name	Location (km from Fed. Br.)	Mean annual flow (6 yrs.) KDAM3	KAF	cfs
010090	David R. abv. Goldville	120.0	157	127	176
010100	David R. at Goldville	118.5	157	127	176
010150	David R. at Tea Kettle Sp.	88.5	157	127	176
010190	David R. blw. Flat Meadow	69.0	162	131	181
010200	J. P. Creek abv. Heather Cr.	169.5	61	50	69
010300	Heather Cr. abv. Asko Creek	157.0	31	25	34
010400	Asko Cr. at Heather Cr.	156.0	31	25	34
010500	Heather Cr. at J. P. Creek	133.5	61	50	69
010590	J. P. Creek abv. Red Mountain	96.0	121	98	135
010600	J. P. Creek at Red Mountain	78.0	130	105	146
010650	J. P. Creek blw. Goat Mountain	61.5	145	117	162
010700	David R. at Blue Gorge	34.5	311	252	348
010800	David R. at Uranium Reach	22.5	311	252	348
010850	David R. at Federal Bridge	0.0	311	252	348

Table 3. Baseline flow for David River below Flat Meadows (cfs).

Yr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
80	85.7	120.5	70.5	123.6	341.3	709.3	308.2	97.3	68.6	84.9	91.2	78.4
81	70.2	87.5	65.8	135.9	266.5	449.8	244.5	196.1	91.3	103.2	100.7	80.6
82	75.7	92.8	56.2	139.6	298.9	480.6	194.7	119.1	62.2	78.0	96.4	81.3
83	83.6	123.1	70.8	130.7	271.4	239.7	261.9	92.5	58.9	90.8	93.7	74.3
84	73.6	93.2	54.1	125.6	352.1	768.7	305.9	202.8	143.8	57.2	93.2	84.3
85	89.7	116.9	62.3	162.4	514.51	106.4	453.3	307.0	207.5	78.9	117.1	90.5

Table 4. Baseline flow for J. P. Creek below Goat Mountain (cfs).

Yr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
80	28.0	28.9	27.2	56.8	307.6	769.8	609.4	171.2	88.3	70.5	44.5	36.2
81	37.1	40.2	31.3	145.9	425.5	777.7	287.5	130.6	98.8	72.4	49.8	41.8
82	41.4	40.2	37.4	152.3	259.4	297.5	123.3	85.6	52.8	58.6	38.2	23.6
83	21.2	4.4	26.1	42.8	287.8	330.8	123.4	78.1	72.8	58.3	43.9	32.7
84	40.4	5.7	45.9	72.1	460.0	1006.6	457.0	230.1	159.5	112.2	69.0	56.3
85	38.3	39.0	35.2	107.2	615.2	918.7	830.0	320.6	171.1	112.3	67.2	44.4

deal of flow escapes the basin without being used each year so it would appear that the region is ripe for development.

5.2 SUNLIGHT VALLEY RESERVOIR OPERATIONS FOR TRANSBASIN DIVERSION

Institutional Setting

Sunlight Valley is a proposed reservoir on the David River in a high mountain area near Big City (Figure 11). The reservoir is being designed to serve as a storage facility and diversion point to shunt water to the sprawling developments on the other side of the Great Divide. The Big City water board has hired a major A/E firm to engineer the entire project, from the technical design to the reservoir operations procedures. The design must give reasonable weight to environmental concerns; specifically, survival of a species of special interest as we will see below.

Big City's primary water right was filed in May of 1916. Although no actual diversion has been made as yet, Big City has exercised "due diligence" in planning, surveying, measuring flow, and all other legal activities required to establish its continued intent to use the water right. The annual volume of water the city plans to divert is 97.5 KDAM3 (79 KAF). Big City filed for an additional diversion (with water right date of January 1945) that will allow combined high-year withdrawals of 161 KDAM3 (130 KAF).

Downstream from Sunlight is an existing Bureau of Reclamation (BOR) facility, Everclear Reservoir, which was built in anticipation of increased upper basin development. It has been in place since the early 1960's. Though Big City's water rights have priority over those served by the operation of Everclear, the operation of Sunlight will not be allowed to negatively impact the existing water use patterns below Everclear. In effect, BOR has planned that Everclear will be used to buffer the water diversion impacts of the Sunlight-Big City operation to protect users in the lower basin.

Hydrologic Setting

The mean annual flow at Goldville is 157 KDAM3 (127 KAF). Mean annual flow at this location ranges from a minimum of 111 KDAM3 (90 KAF) to a maximum of 246 KDAM3 (200 KAF). Big City's dry and average year demand of 97.5 KDAM3 appears to fall well within the minimum annual flow.

Similarly, the combined downstream water rights in the basin place a demand in average years of 159.6 KDAM3 on the upper basin, which compares favorably to the 311 KDAM3 mean annual flow.

Tables 5, 6, and 7 summarize the demand patterns that will be exerted by the various water uses on the upper basin (including users below Federal Bridge). Table 8 shows mean monthly flows at Federal Bridge for 1980-85, and Table 9 shows the mean monthly flow at Federal Bridge after Big City demands are removed. Big City plans to install a tunnel with 25 KDAM3/month capacity as part of this project. This is reflected by the maximum delivery shown in the wet year (1985).

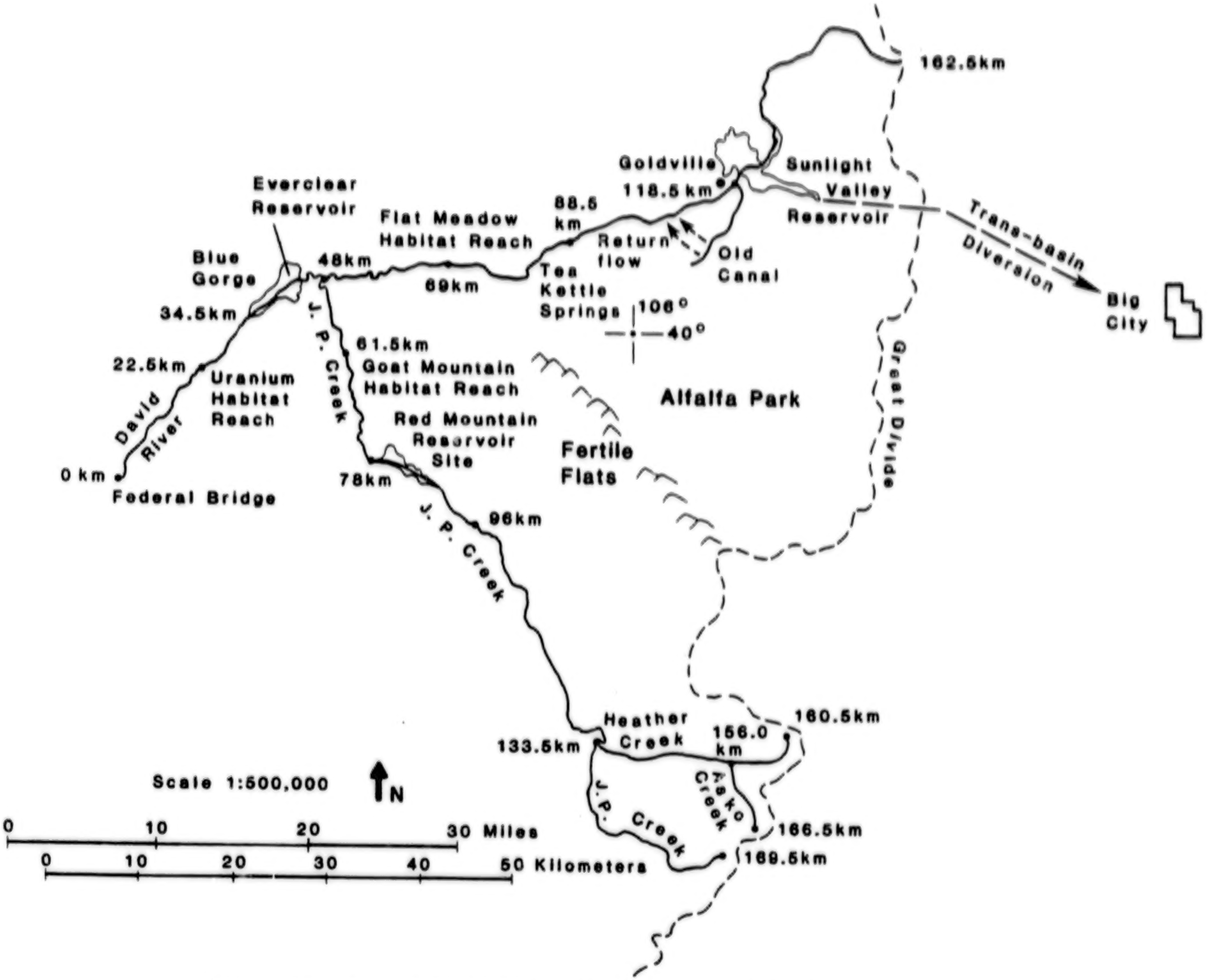


Figure 11. Map of David River basin showing proposed transbasin diversion from Sunlight Valley reservoir.

Table 5. Big City demands (diverted entirely from basin, KDAM3).

Yr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
80	1.5	1.5	1.5	3.0	4.5	15.0	20.0	20.0	15.0	10.0	4.0	1.5	97.5
81	1.5	1.5	1.5	3.0	4.5	15.0	20.0	20.0	15.0	10.0	4.0	1.5	97.5
82	1.5	1.5	1.5	3.0	4.5	15.0	20.0	20.0	15.0	10.0	4.0	1.5	97.5
83	1.5	1.5	1.5	3.0	4.5	15.0	20.0	20.0	15.0	10.0	4.0	1.5	97.5
84	1.5	1.5	1.5	3.0	4.5	15.0	20.0	20.0	15.0	10.0	4.0	1.5	97.5
85	2.0	2.0	2.0	8.0	20.0	25.0	25.0	25.0	25.0	20.0	5.0	2.0	161.0

Table 6. Old Alfalfa Park water rights (KDAM3).

Yr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
80					2.8	4.2	6.2	5.5	3.1	1.1			22.9
81					2.2	5.5	4.4	6.1	4.5	0			22.7
82					2.6	3.7	4.5	5.4	3.0	1.8			21.0
83					3.8	6.0	1.8	4.8	3.2	1.0			20.6
84					4.1	5.5	7.3	7.4	4.6	2.8			31.7
85					3.5	4.5	7.3	7.6	5.0	3.0			30.9

Table 7. Aggregate lower basin water rights (KDAM3).

Yr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
80	5.0	4.5	5.0	4.8	7.0	12.0	22.0	17.0	9.0	6.0	4.8	5.0	159.6
81	5.0	4.5	5.0	4.8	7.0	12.0	22.0	17.0	9.0	6.0	4.8	5.0	159.6
82	5.0	4.5	5.0	4.8	6.0	10.0	16.0	12.0	6.0	6.0	4.8	5.0	156.7
83	5.0	4.5	5.0	4.8	6.0	10.0	16.0	12.0	6.0	6.0	4.8	5.0	127.1
84	5.0	4.5	5.0	4.8	7.0	12.0	22.0	25.0	12.0	8.0	4.8	5.0	159.6
85	7.0	6.5	7.0	6.8	8.0	18.0	30.0	35.0	22.0	10.0	6.8	7.0	222.3

Table 8. Federal Bridge mean monthly flows 1980-85 (KDAM3).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
6.6	7.2	5.3	15.2	56.6	98.1	55.3	27.2	15.0	10.0	8.1	6.7	311.3

Table 9. Federal Bridge monthly flows with Big City demands removed (KDAM3).

Yr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
80	5.0	6.9	3.9	8.3	45.3	95.5	52.2	1.3	-4.7	-0.8	3.2	4.9	221.0
81	4.5	5.4	3.8	15.9	48.1	77.1	22.8	6.2	-1.3	-0.4	4.3	5.5	192.1
82	5.4	5.8	3.6	16.6	38.2	43.2	5.0	-3.3	-7.7	-1.6	3.0	4.0	112.2
83	4.3	5.4	3.8	7.8	39.2	28.6	10.1	-6.7	-6.3	-1.2	3.4	4.3	92.7
84	5.1	3.4	4.0	9.6	58.8	118.3	40.9	15.1	6.9	1.1	4.6	6.6	274.4
85	5.5	6.9	3.4	10.0	67.2	126.1	76.0	25.3	2.8	-7.1	5.2	5.6	326.6

Considering the annual total values in Table 9, it appears there may be insufficient water left after the Big City diversion to satisfy the downstream water right holders in years 1982 and 1983. Table 9 was obtained by simple subtraction, so the effects of J. P. Creek were not considered and the negative values shown are somewhat unrealistic. The negative values do, however, serve as an index of the areas of potential conflict between upper basin and lower basin water use. These conflicts can be largely eliminated by inclusion of storage in the system as described earlier.

Big City's consultants have performed a standard operation study using the HYDROSS model to design an operating scheme that will allow Big City to divert the water it is entitled to with minimum impacts on the other water uses in the basin. Their study includes operation of Everclear Reservoir. The study indicates that over the 6-year study period (1980-1985) the desired volumes of water can be supplied to all water users at all times with one small exception. The old Alfalfa Park water users will be called out by prior rights in July and August of 1983 (the driest year). Since this means the farmers in Alfalfa Park will still be able to get one cutting of their crop in such a year, the study is considered to represent an acceptable water management scheme.

Tables 10 and 11 show the flows delivered to Flat Meadow and Goat Mountain under the operation study scenario. The Sunlight Reservoir operation is summarized in Figure 12. Note that the reservoir storage falls below half of the active storage volume available. If a more prolonged dry period occurred than is described with the 6 years used for this study the reservoir may be drained nearly dry.

Biological Setting

Everclear Reservoir effectively divides the David River into two parts, an upper basin and a lower basin. The dam is a true biological barrier as it allows no migration between basins. The historical population of bravefish has been fragmented by this dam and is struggling to survive above the existing reservoir. In fact, the bravefish is a candidate for inclusion on the threatened list provided by the Endangered Species Act. Warmer temperatures in the lower basin many kilometers downstream from Everclear Reservoir are the preferred habitat of the bravefish, although some do exist in the Uranium habitat reach. In contrast, only a relic breeding population exists above the dam. For reasons not fully understood, the bravefish in the upper basin only spawn in the Flat Meadow habitat reach. One key seems to be the warming influence of Tea Kettle Springs; the bravefish appear to require temperatures of at least 20 °C sometime during the June to August spawning period in order to trigger spawning behavior.

Flat Meadow is not particularly good for lifestages of bravefish other than prespawning and spawning, due to its fine gravel substrate. Instead, other lifestages prefer the Goat Mountain reach on J. P. Creek. Even though the nonbreeding adult habitat is almost all concentrated at the Goat Mountain site, that site itself is not particularly good habitat. In short, the habitat in the entire upper basin is poor, which is presumably why the bravefish are rare. Since these fish are in a delicate balance with their habitat, any time the winter habitat (November through February) is low, it becomes imperative that spawning habitat conditions in the Flat Meadow reach compensate. In other words, a bad winter followed immediately by an equally bad spawning season risks propelling these fish towards the endangered list.

The Flat Meadows habitat site is representative of a stream segment 12.6 miles (20.3 km) long, reaching almost all the way down to the junction with J. P. Creek. The Goat Mountain habitat site is representative of a shorter section of stream, 8.1 miles (13 km) on J. P. Creek, immediately upstream of the junction with the David River. There are no known reasons why movement between these two areas would be restricted except in cases of nearly zero discharge on either stream. The habitat flow relationships at the two sites are given in Tables 12 and 13.

Preliminary data suggest that there is a requirement for a certain number of degree-days accumulated during the prespawning period (March - August) at the spawning site. Though the exact relationships are not well understood, it is felt that at least 500 degree-days (benchmark 5 °C) are required to ensure a successful spawning season. Biologists are unsure as to whether there is any compensatory relationship between degree-days and the amount of spawning habitat. This is unfortunate, because the altered flows at Flat Meadow are likely to reduce the available microhabitat but increase the degree-days.

Table 10. Simulated flows for David River below Flat Meadow (cfs).

Yr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
80	66.8	64.1	50.7	33.7	104.6	384.9	62.9	68.7	66.3	55.3	47.8	58.6
81	51.2	34.1	33.5	33.7	40.0	55.5	77.3	70.5	72.2	56.0	52.2	52.2
82	49.3	53.0	33.5	33.7	41.2	217.8	57.0	64.1	63.0	55.8	54.3	66.4
83	65.2	88.7	51.1	47.7	44.7	56.4	77.2	65.8	63.7	53.3	49.7	58.3
84	51.2	71.3	34.3	33.7	45.6	58.4	70.4	78.8	77.2	66.9	52.3	41.8
85	54.5	34.1	35.9	33.7	43.9	405.6	136.5	105.4	78.2	68.7	53.5	54.5

Table 11. Simulated flows for J. P. Creek below Goat Mountain (cfs).

Yr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
80	27.2	28.9	27.2	56.8	299.3	751.7	580.0	136.1	55.7	48.8	33.4	32.3
81	36.3	40.2	31.3	145.9	419.0	760.4	258.0	93.6	60.4	49.8	38.7	38.5
82	41.4	40.2	37.4	152.3	251.7	281.2	99.8	55.0	23.4	36.3	25.7	18.7
83	19.9	4.4	26.1	42.8	276.6	308.2	94.7	45.9	42.8	38.5	33.4	28.9
84	39.7	5.7	45.9	72.1	447.9	981.9	420.1	184.8	115.9	78.9	50.4	48.8
85	36.3	39.0	35.2	107.2	604.9	898.1	796.0	276.6	126.6	77.1	47.4	36.3

Table 12. Habitat-flow relationship for bravefish spawning at Flat Meadow.

Discharge (cfs)	Spawning area available (sq. ft./1000 ft. of stream)
0.00	0.00
200.00	10000.00
300.00	40000.00
500.00	20000.00
600.00	0.00
9999.99	0.00

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REPORT 020 STA=010100                                                        HYDROSS VER 2.0  10/31/78

                                   HYDROSS REPORT 020                        DATE RUN% MAY 31,1986 1925
                         FILE HRS2OUT  A/O DATE% MAY 31,1986 1924            PAGE 025
                   STREAM NETWORK HABITAT CASE STUDY NO. 2 -- SUNLIGHT VALLEY UNITS% KDAM3

STATION 010100 ON STREAM ORDER 01 AT TOP OF REACH DAVID RIVER AT GOLDVILLE -- SUNLIGHT VAL
 AREA-CAPACITY TABLE%
  ELEVATION......(M) 1874.50 1880.60 1886.70 1898.90 1899.70 1905.00 1911.10 1917.20 1923.30 1929.40 1938.50 1950.70
  AREA.........(KHA)    0.00     .05     .13     .26     .65     .91    1.30    1.60    1.70    2.00    2.20    2.60
  CAPACITY...(KDAM3)    0.00     .80    8.10   30.40   67.20  125.10  208.50  301.50  416.10  537.20  670.10  946.10
  MAX DISCH...(M3/S)    0.00   30.00   30.00   30.00   30.00   40.00   50.00   60.00   70.00   80.00   90.00  110.00
 DEAD CONTENTS......    5.00 KDAM3
 SPILL CONTENTS.....  180.00 KDAM3

                        JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT     NOV     DEC   YEARLY   YEARLY
                       1980    1980    1980    1980    1980    1980    1980    1980    1980    1980    1980    1980    TOTAL  AVERAGE
MAXIMUM CONTENTS     180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00
MINIMUM CONTENTS      20.00   20.00   20.00   20.00   70.00  140.00  130.00  110.00   20.00   20.00   20.00   20.00
END-OF-MON CONTENTS  150.00  152.37  152.37  155.19  168.26  177.03  176.31  159.61  146.40  140.30  140.30  140.60   1858.7   154.89
CHANGE IN CONTENTS     0.00    2.37    -.00    2.83   13.07    8.76    -.71  -16.70  -13.21   -6.10    -.00     .30     -9.4     -.78
END-OF-MON ELEV (M) 1906.82 1906.99 1906.99 1907.20 1908.16 1908.80 1908.75 1907.52 1906.56 1906.11 1906.11 1906.13
CHANGE IN ELEVATION    0.00     .17    0.00     .21     .96     .64    -.05   -1.22    -.97    -.45    0.00     .02      -.7     -.06
SURFACE AREA (KHA)     1.03    1.04    1.04    1.05    1.11    1.15    1.15    1.07    1.01     .98     .98     .98
UNIT EVAP (MM)         0.00    0.00    0.00   74.00   93.00  122.00  134.00  139.00   74.00    0.00    0.00    0.00
EVAPORATION            0.00    0.00    0.00     .77    1.01    1.38    1.54    1.54     .77    0.00    0.00    0.00      7.0      .58
SPILLS                 0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0.0     0.00

                        JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT     NOV     DEC   YEARLY   YEARLY
                       1981    1981    1981    1981    1981    1981    1981    1981    1981    1981    1981    1981    TOTAL  AVERAGE
MAXIMUM CONTENTS     180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00
MINIMUM CONTENTS      20.00   20.00   20.00   20.00   70.00  140.00  130.00  110.00   20.00   20.00   20.00   20.00
END-OF-MON CONTENTS  140.60  142.76  143.71  147.36  159.54  173.52  166.76  157.58  145.88  141.16  141.54  142.45   1802.9   150.24
CHANGE IN CONTENTS     0.00    2.16     .95    3.66   12.18   13.97   -6.76   -9.18  -11.70   -4.72     .38     .90      1.8      .15
END-OF-MON ELEV (M) 1906.13 1906.29 1906.36 1906.63 1907.52 1908.54 1908.05 1907.38 1906.52 1906.17 1906.20 1906.27
CHANGE IN ELEVATION    0.00     .16     .07     .27     .89    1.02    -.49    -.67    -.86    -.35     .03     .07       .1      .01
SURFACE AREA (KHA)      .98     .99    1.00    1.01    1.07    1.14    1.10    1.06    1.01     .99     .99     .99
UNIT EVAP (MM)         0.00    0.00    0.00   84.00   95.00  112.00  149.00  139.00   90.00    0.00    0.00    0.00
EVAPORATION            0.00    0.00    0.00     .84     .99    1.24    1.67    1.51     .93    0.00    0.00    0.00      7.2      .60
SPILLS                 0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0.0     0.00

                        JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT     NOV     DEC   YEARLY   YEARLY
                       1982    1982    1982    1982    1982    1982    1982    1982    1982    1982    1982    1982    TOTAL  AVERAGE
MAXIMUM CONTENTS     180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00
MINIMUM CONTENTS      20.00   20.00   20.00   20.00   70.00  140.00  130.00  110.00   20.00   20.00   20.00   20.00
END-OF-MON CONTENTS  142.95  144.17  144.39  148.21  162.69  166.79  157.35  142.41  128.64  122.01  122.01  122.01   1703.6   141.97
CHANGE IN CONTENTS      .50    1.23     .22    3.82   14.47    4.10   -9.44  -14.95  -13.76   -6.63    -.00    0.00    -20.4    -1.70
END-OF-MON ELEV (M) 1906.31 1906.40 1906.41 1906.69 1907.75 1908.05 1907.36 1906.27 1905.26 1904.72 1904.72 1904.72
CHANGE IN ELEVATION     .04     .09     .02     .28    1.06     .30    -.69   -1.09   -1.01    -.54    0.00    0.00     -1.6     -.13
SURFACE AREA (KHA)      .99    1.00    1.00    1.02    1.09    1.10    1.06     .99     .93     .90     .90     .90
```

Figure 12. HYDROSS model output tabulating contents and operation of proposed Sunlight Valley reservoir operations.

```
REPORT 020 STA=010100                                                                                   HYDROSS VER 2.0  10/31/78

                                                     HYDROSS REPORT 020                                 DATE RUN% MAY 31,1986 1925
                                             FILE HRS2OUT  A/O DATE% MAY 31,1986 1924                   PAGE 026
                                       STREAM NETWORK HABITAT CASE STUDY NO. 2 -- SUNLIGHT VALLEY       UNITS% KDAM3

STATION 010100 CN STREAM ORDER 01(CONTINUED)      DAVID RIVER AT GOLDVILLE -- SUNLIGHT VAL

                         JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT     NOV     DEC   YEARLY  YEARLY
                        1982    1982    1982    1982    1982    1982    1982    1982    1982    1982    1982    1982    TOTAL AVERAGE
 UNIT EVAP (MM)         0.00    0.00    0.00   94.00  110.00  126.00  153.00  140.00   89.00    0.00    0.00    0.00
 EVAPORATION            0.00    0.00    0.00     .95    1.16    1.38    1.66    1.44     .85    0.00    0.00    0.00      7.4     .62
 SPILLS                 0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0.0    0.00

                         JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT     NOV     DEC   YEARLY  YEARLY
                        1983    1983    1983    1983    1983    1983    1983    1983    1983    1983    1983    1983    TOTAL AVERAGE
 MAXIMUM CONTENTS     180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00
 MINIMUM CONTENTS      20.00   20.00   20.00   20.00   70.00  140.00  130.00  110.00   20.00   20.00   20.00   20.00
 END-OF-MON CONTENTS  122.01  122.87  122.87  125.24  137.67  136.36  131.05  114.26  100.21   94.55   94.55   94.55   1396.2  116.35
 CHANGE IN CONTENTS     -.00     .86    -.00    2.37   12.43   -1.31   -5.31  -16.79  -14.05   -5.66    0.00    0.00    -27.5   -2.29
 END-OF-MON ELEV (M) 1904.72 1904.80 1904.80 1905.01 1905.92 1905.82 1905.44 1904.01 1902.72 1902.20 1902.20 1902.20
 CHANGE IN ELEVATION    0.00     .08    0.00     .21     .91    -.10    -.39   -1.43   -1.29    -.52    0.00    0.00     -2.5    -.21
 SURFACE AREA (KHA)      .90     .90     .90     .91     .97     .96     .94     .86     .80     .77     .77     .77
 UNIT EVAP (MM)         0.00    0.00    0.00   80.00  118.00  148.00  157.00  140.00  108.00    0.00    0.00    0.00
 EVAPORATION            0.00    0.00    0.00     .72    1.11    1.43    1.49    1.26     .90    0.00    0.00    0.00      6.9     .58
 SPILLS                 0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0.0    0.00

                         JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT     NOV     DEC   YEARLY  YEARLY
                        1984    1984    1984    1984    1984    1984    1984    1984    1984    1984    1984    1984    TOTAL AVERAGE
 MAXIMUM CONTENTS     180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00
 MINIMUM CONTENTS      20.00   20.00   20.00   20.00   70.00  140.00  130.00  110.00   20.00   20.00   20.00   20.00
 END-OF-MON CONTENTS   94.81   94.81   94.81   97.99  116.83  154.80  154.25  145.66  137.85  129.65  130.02  132.31   1483.8  123.65
 CHANGE IN CONTENTS      .26    0.00    0.00    3.18   18.84   37.97    -.56   -8.59   -7.81   -8.20     .37    2.29     37.8    3.15
 END-OF-MON ELEV (M) 1902.23 1902.23 1902.23 1902.52 1904.24 1907.17 1907.13 1906.50 1905.93 1905.33 1905.36 1905.53
 CHANGE IN ELEVATION     .02    0.00    0.00     .29    1.72    2.93    -.04    -.63    -.57    -.60     .03     .17      3.3     .28
 SURFACE AREA (KHA)      .77     .77     .77     .79     .87    1.05    1.05    1.01     .97     .93     .93     .94
 UNIT EVAP (MM)         0.00    0.00    0.00   73.00   99.00  102.00  116.00  139.00   90.00    0.00    0.00    0.00
 EVAPORATION            0.00    0.00    0.00     .57     .82     .98    1.22    1.43     .89    0.00    0.00    0.00      5.9     .49
 SPILLS                 0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0.0    0.00

                         JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT     NOV     DEC   YEARLY  YEARLY
                        1985    1985    1985    1985    1985    1985    1985    1985    1985    1985    1985    1985    TOTAL AVERAGE
 MAXIMUM CONTENTS     180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00  180.00
 MINIMUM CONTENTS      20.00   20.00   20.00   20.00   70.00  140.00  130.00  110.00   20.00   20.00   20.00   20.00
 END-OF-MON CONTENTS  133.14  136.81  136.81  137.66  153.07  180.00  180.00  172.02  158.95  142.39  143.51  144.86   1819.2  151.60
 CHANGE IN CONTENTS      .83    3.67    0.00     .84   15.41   26.93    0.00   -7.98  -13.08  -16.56    1.12    1.35     12.5    1.05
 END-OF-MON ELEV (M) 1905.59 1905.86 1905.86 1905.92 1907.05 1909.02 1909.02 1908.43 1907.48 1906.26 1906.35 1906.45
 CHANGE IN ELEVATION     .06     .27    0.00     .06    1.13    1.97    0.00    -.58    -.96   -1.21     .08     .10       .9     .08
 SURFACE AREA (KHA)      .95     .96     .96     .97    1.04    1.17    1.17    1.13    1.07     .99    1.00    1.00
 UNIT EVAP (MM)         0.00    0.00    0.00   63.00  106.00   92.00  138.00  139.00   76.00    0.00    0.00    0.00
 EVAPORATION            0.00    0.00    0.00     .61    1.07    1.02    1.61    1.60     .84    0.00    0.00    0.00      6.7     .56
 SPILLS                 0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0.0    0.00

MONTHLY AVERAGES FOR PERIOD 1980-1985
                         JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT     NOV     DEC
 END-OF-MON CONTENTS  130.59  132.30  132.49  135.28  149.68  164.75  160.95  148.59  136.32  128.34  128.66  129.46
 HIGHEST CONTENTS     150.00  152.37  152.37  155.19  168.26  180.00  180.00  172.02  158.95  142.39  143.51  144.86
 LOWEST CONTENTS       94.81   94.81   94.81   97.99  116.83  136.36  131.05  114.26  100.21   94.55   94.55   94.55
 EVAPORATION            0.00    0.00    0.00     .74    1.02    1.24    1.53    1.46     .86    0.00    0.00    0.00
 SPILLS                 0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
```

Figure 12. (Concluded)

Table 13. Habitat flow relationship for bravefish adults at Goat Mountain.

Discharge (cfs)	Adult habitat available (sq. ft./1000 ft. of stream)
0.00	0.00
25.00	24000.00
60.00	40000.00
100.00	30000.00
500.00	30000.00
9999.99	30000.00

5.3 CHARGE TO THE ANALYST

You have been asked by Big City's consulting firm to recommend an operation scheme that will keep Big City's project from being blocked because of adverse impacts to the bravefish, while at the same time allowing the maximum amount of water to be delivered (preferably in the given pattern). Though Everclear Reservoir has been in place since the 1960's, it does not influence the flow patterns upstream of the confluence of the David River and J. P. Creek. Thus, the baseline condition in the upper basin is essentially natural flow except for the small influence of the Old Alfalfa Park diversion. You should try to provide maximum flexibility in your recommendation. For example, you may wish to suggest certain operations criteria in specific kinds of water years to provide needed habitat.

5.4 ONE ITERATION OF THE ANALYSIS

Programs to be Run

The consultant's hydrologist has run HYDROSS to simulate the city's proposed project operation; so the next step in the analysis is to run the linkage programs and models that will produce habitat values that will be used in developing a recommendation. Since temperature plays an important part in the bravefish life cycle, the following series of programs should be applied to generate the output from which the analysis will be performed. They are: SNTEMP (which must be run with a calibration data set taken from measured weather, stream flow, and water temperature data), LNKQ2T (to link HYDROSS to the temperature model), LNKT2H (to generate stream network habitat values conditioned with temperature), and LNKT2TS (to generate temperature and flow time series and degree-days).

The first iteration of the analysis for this situation consists of generating the habitat and degree-day response for the baseline and proposed project scenarios, evaluating their results, and preparing to feed those results back through the analysis again. In preparation for generating the habitat response, the baseline temperature simulation using SNTEMP must be run. (Documentation for SNTEMP is contained in Theurer et al. (1984) and will not be repeated here.) It is imperative that SNTEMP and HYDROSS, or any other basin water management model used in this kind of analysis, be set up so that both models truly represent the same network. (This is not a trivial problem but is beyond the scope of this document). Once SNTEMP is working satisfactorily, LNKQ2T can be set up and run (as described in the appendix) to link the HYDROSS simulation of the proposed project operation scenario with SNTEMP. This will produce a new hydrology data file that can be used in SNTEMP to generate the simulated temperature regime resulting from the project operation scenario (the proposed condition). Note that since SNTEMP does not simulate reservoir temperatures, other techniques must be used to specify release temperatures from Sunlight Reservoir.

The habitat responses are obtained using LNKT2H. LNKT2H is used to sum the spawning habitat at all sites in the basin. (In this example there is only one spawning site, in general there would be several.) LNKT2H should also be used to sum the adult habitat at all sites (again only one site used here). If there are subpopulations of the species of interest, sums across their ranges within the network should also be generated. When these programs have been run, aggregate time series for both life stages, with temperature conditioning and total length of stream included, will have been generated.

Finally, duration and time series plots and data summaries are obtained using LPTDUR and LPTTS from the IFG time series analysis library (TSLIB). LPTDUR was run three times for the following combinations of time series data:

(1) baseline and proposed adult habitat,

(2) baseline and proposed spawning habitat, and

(3) baseline and proposed degree-days.

LPTTS was run once to produce a plot of baseline and proposed habitat time series for both life stages (four variables on the plot). More plots may be necessary when the life stages overlap or the magnitudes of habitat for several life stages are similar and cannot be easily distinguished on one plot.

Output from these models and linkage programs is evaluated as described below.

Evaluating the Output

Question 1. Is there a sufficient number and frequency of long-term life cycle events?

Figure 13 shows the adult and spawning habitat time series output from program LPTTS. Over the period of the study there is no year in which adult or spawning habitat does not occur. Under the proposed condition, basinwide spawning habitat is considerably different from baseline levels in some years. While habitat for spawning is not eliminated under the proposed operation scenario, it appears to deserve further attention as the analysis proceeds,

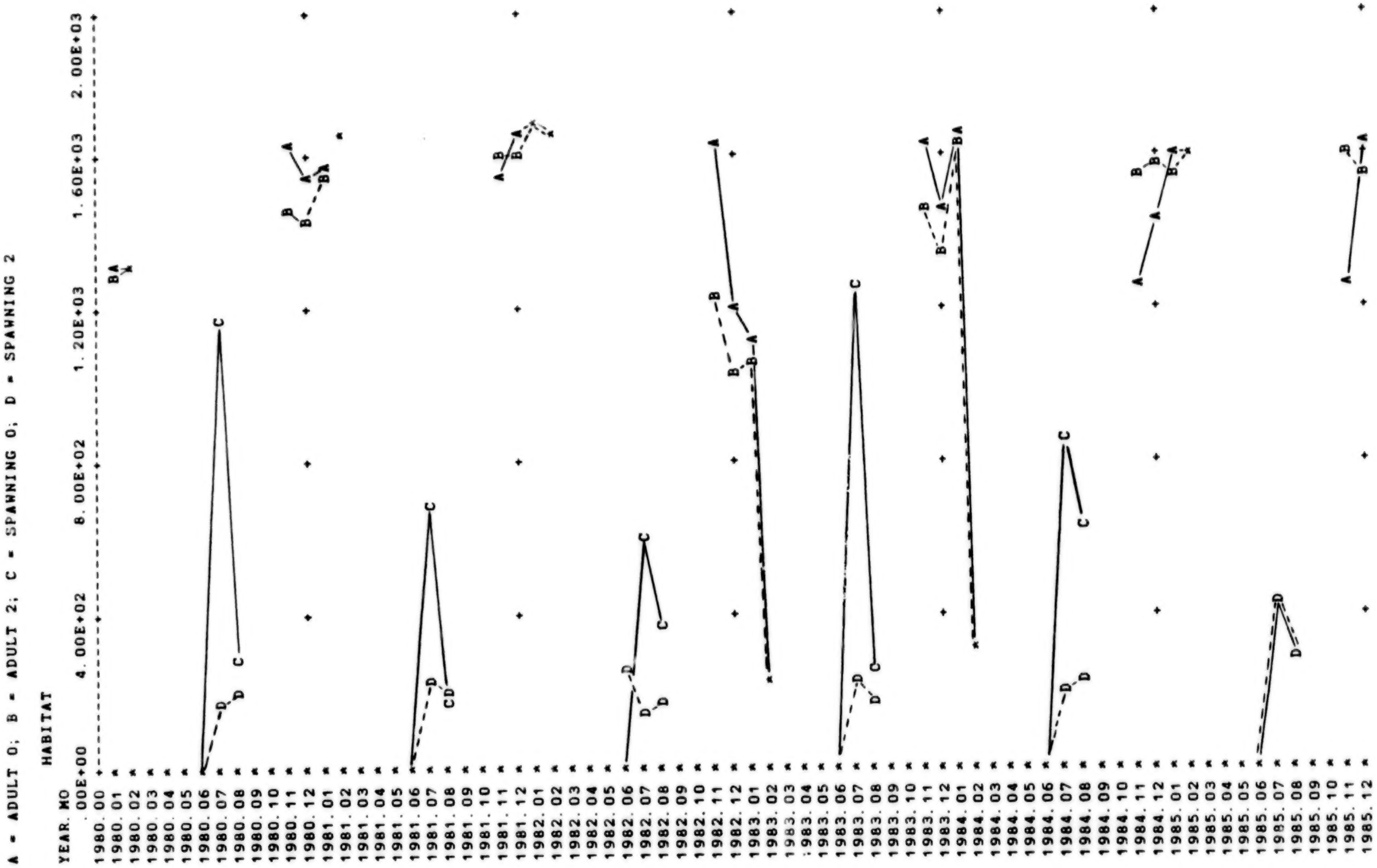

Figure 13. Time series plot of basinwide total bravefish spawning and adult habitat.

because it seems to be reduced to less than half of the baseline value in most months of the study period.

An alternative output for determining if there are multiyear gaps in important life stage events is the data summary table found at the beginning of the LPTDUR output. Since this data is tabular, rather than plotted, it is easy to scan for zero values where nonzero values are expected. In addition, the tables preceding each duration plot in the LPTDUR output array the data in sorted order for individual months, so those tables can be used to determine how often threshold values are exceeded in a given month.

This approach is used to determine if sufficient degree-days are accumulated to induce spawning. Figure 14 shows the baseline and proposed cumulative degree-day values in the Flat Meadow reach where spawning occurs. There is only one year under the baseline scenario were the minimum 500 degree-days is not accumulated, but the 500 degree-day threshold is often not reached until April or May. In contrast, the proposed operation scenario produces 500 degree-days earlier in the year, each year, including the high flow year when the minimum is not met under the baseline condition. Figure 15 shows the sorted degree-day values for June. Note how often 500 degree-days are accumulated under each scenario.

With the exception of spawning habitat, it appears that all life stages under both scenarios occur with sufficient frequency and magnitude. That is, there are no periods when several years elapse without at least minimum habitat for critical life stages.

Question 2. When do basinwide changes in aggregate habitat values occur?

First, considering spawning, look at the LPTDUR summary output graph and final summary tables (Figures 16 through 18). Changes between the baseline scenario and proposed scenario for July and August are all negative for both indices, the mean, and the median except for a small increase in index A in August. Generally, spawning across all months is depressed by 25% to 70% under the proposed scenario.

The situation is less dramatic for overwintering adults. There is a slight reduction in the mean and median habitat but no reduction in indices A or B (Figures 19 through 22). All changes are within 5% and may be an artifact of the way the model simulated the flows in J. P. Creek rather than a real change.

The degree-day values show a great increase between scenarios. The median number of accumulated degree-days increases from 80% to 500%. Under the proposed management regime, the stimulus required to initiate spawning occurs in all years, occurs earlier in the year, and significantly exceeds the threshold value in most years. Figures 23 through 26 show these increases.

```
        DATE -  86/05/21.          TIME -  13.26.54.          PROGRAM - LPTDUR

     FIRST DATA SET IS -
     TEMPERATURE TO HABITAT MODEL RUN FOR CASE 0 & 2
     DAVID RIVER      0           69.0FLAT MEADOW HABITAT REACH

   YEAR      JAN        FEB        MAR        APR        MAY        JUNE       JULY        AUG        SEPT       OCT         NOV          DEC

   1980          .00       4.00     110.00     287.00     516.00     736.00    1142.00    1652.00    2017.00    2170.00         .00          .00
   1981          .00        .00      29.00     137.00     362.00     629.00    1034.00    1439.00    1704.00    1802.00         .00          .00
   1982          .00       1.00      94.00     318.00     575.00     896.00    1505.00    1994.00    2348.00    2502.00         .00          .00
   1983          .00       9.00      83.00     274.00     546.00     896.00    1327.00    1774.00    2094.00    2245.00         .00          .00
   1984          .00        .00      37.00     195.00     396.00     600.00     987.00    1424.00    1700.00    1846.00         .00          .00
   1985          .00        .00      65.00     225.00     397.00     551.00     849.00    1180.00    1449.00    1606.00         .00          .00

        DATE -  86/05/21.          TIME -  13.26.54.          PROGRAM - LPTDUR

     SECOND DATA SET IS -
     TEMPERATURE TO HABITAT MODEL RUN FOR CASE 0 & 2
     DAVID RIVER      0           69.0FLAT MEADOW HABITAT REACH

   YEAR      JAN        FEB        MAR        APR        MAY        JUNE       JULY        AUG        SEPT       OCT         NOV          DEC

   1980          .00       4.00     113.00     314.00     644.00     966.00    1484.00    2015.00    2382.00    2539.00         .00          .00
   1981          .00        .00      32.00     160.00     470.00     882.00    1377.00    1836.00    2111.00    2215.00         .00          .00
   1982          .00       1.00      98.00     355.00     713.00    1152.00    1810.00    2317.00    2673.00    2829.00         .00          .00
   1983          .00      10.00      88.00     306.00     665.00    1101.00    1619.00    2082.00    2403.00    2560.00         .00          .00
   1984          .00        .00      39.00     222.00     546.00     972.00    1496.00    2000.00    2302.00    2450.00         .00          .00
   1985          .00        .00      71.00     277.00     608.00     913.00    1380.00    1828.00    2154.00    2320.00         .00          .00
```

Figure 14. Degree-day summary tables from program LPTDUR for the baseline and proposed scenarios.

```
DATE -  86/05/21.          TIME -  13.26.54.          PROGRAM - LPTDUR
                JUNE       DEGREE DAYS AT FLAT MEADOW


 ORDERED MONTHLY DATA FOR, JUNE
                                    CASE 0                  CASE 2
 ORDER    PLOTTING
NUMBER     POINT      YEAR        ELEMENT      YEAR        ELEMENT

    1       8.33      1982         896.00      1982        1152.00
    2      25.00      1983         896.00      1983        1101.00
    3      41.67      1980         736.00      1984         972.00
    4      58.33      1981         629.00      1980         966.00
    5      75.00      1984         600.00      1985         913.00
    6      91.67      1985         551.00      1981         882.00
```

Figure 15. Sorted degree-day tables for June from program LPTDUR for the baseline and proposed scenarios.

```
         DATE -  86/06/03.          TIME -  14.39.55.          PROGRAM - LPTDUR


                       SUMMARY STATISTICS

MONTH                AVERAGE                    MEDIAN                   INDEX - A                  INDEX - B
           CASE 0         CASD 2       CASE 0        CASD 2       CASE 0        CASD 2       CASE 0        CASD 2

JAN             .00          .00          .00           .00          .00           .00          .00           .00
FEB             .00          .00          .00           .00          .00           .00          .00           .00
MARCH           .00          .00          .00           .00          .00           .00          .00           .00
APRIL           .00          .00          .00           .00          .00           .00          .00           .00
MAY             .00          .00          .00           .00          .00           .00          .00           .00
JUNE            .00        46.40          .00           .00          .00           .00          .00         23.49
JULY         786.17       257.75       800.34        236.43       575.39        208.42       821.76        244.20
AUG          312.56       237.06       306.56        222.43       211.59        213.10       307.42        232.00
SEPT            .00          .00          .00           .00          .00           .00          .00           .00
OCT             .00          .00          .00           .00          .00           .00          .00           .00
NOV             .00          .00          .00           .00          .00           .00          .00           .00
DEC             .00          .00          .00           .00          .00           .00          .00           .00
```

Figure 16. LPTDUR summary statistics for spawning.

```
DATE -  86/06/03.          TIME -  14.39.55.         PROGRAM - LPTDUR

          MONTH     CHANGE IN INDEX - A           CHANGE IN INDEX - B           CHANGE IN AVERAGE             CHANGE IN MEDIAN

          JAN                      .00                           .00                           .00                           .00
          FEB                      .00                           .00                           .00                           .00
          MARCH                    .00                           .00                           .00                           .00
          APRIL                    .00                           .00                           .00                           .00
          MAY                      .00                           .00                           .00                           .00
          JUNE                     .00                    **********                    **********                           .00
          JULY                  -63.78                        -70.28                        -67.21                        -70.46
          AUG                      .71                        -24.53                        -24.15                        -27.44
          SEPT                     .00                           .00                           .00                           .00
          OCT                      .00                           .00                           .00                           .00
          NOV                      .00                           .00                           .00                           .00
          DEC                      .00                           .00                           .00                           .00
```

Figure 17. LPTDUR summary table of percent changes in spawning.

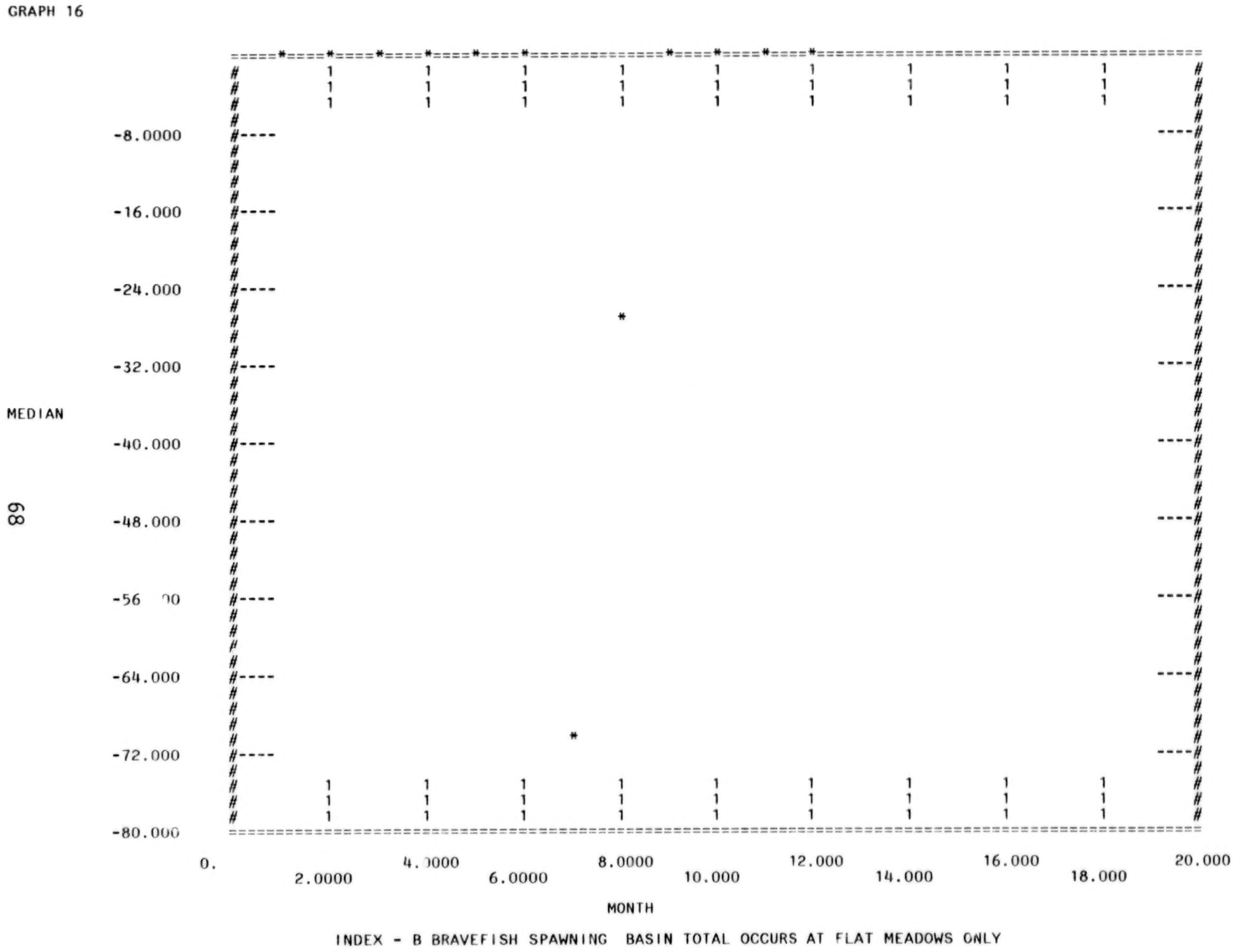

Figure 18. LPTDUR summary plot of percent change in median spawning.

```
          DATE -  86/05/21.          TIME -  15.21.39.         PROGRAM - LPTDUR


                    SUMMARY STATISTICS

MONTH                 AVERAGE                          MEDIAN                          INDEX - A                        INDEX - B
          CASE 0               CASE 2          CASE 0          CASE 2          CASE 0             CASE 2          CASE 0             CASE 2

JAN        1514.50          1485.17         1610.00         1566.00             .00                .00               .00                .00

FEB        1159.45          1159.45         1498.50         1498.50             .00                .00               .00                .00

MARCH          .00              .00             .00             .00             .00                .00               .00                .00

APRIL          .00              .00             .00             .00             .00                .00               .00                .00

MAY            .00              .00             .00             .00             .00                .00               .00                .00

JUNE           .00              .00             .00             .00             .00                .00               .00                .00

JULY           .00              .00             .00             .00             .00                .00               .00                .00

AUG            .00              .00             .00             .00             .00                .00               .00                .00

SEPT           .00              .00             .00             .00             .00                .00               .00                .00

OCT            .00              .00             .00             .00             .00                .00               .00                .00

NOV        1515.50          1509.33         1606.50         1527.50             .00                .00               .00                .00

DEC        1514.17          1445.67         1523.50         1510.00             .00                .00               .00                .00
```

Figure 19. LPTDUR summary statistics for adult habitat.

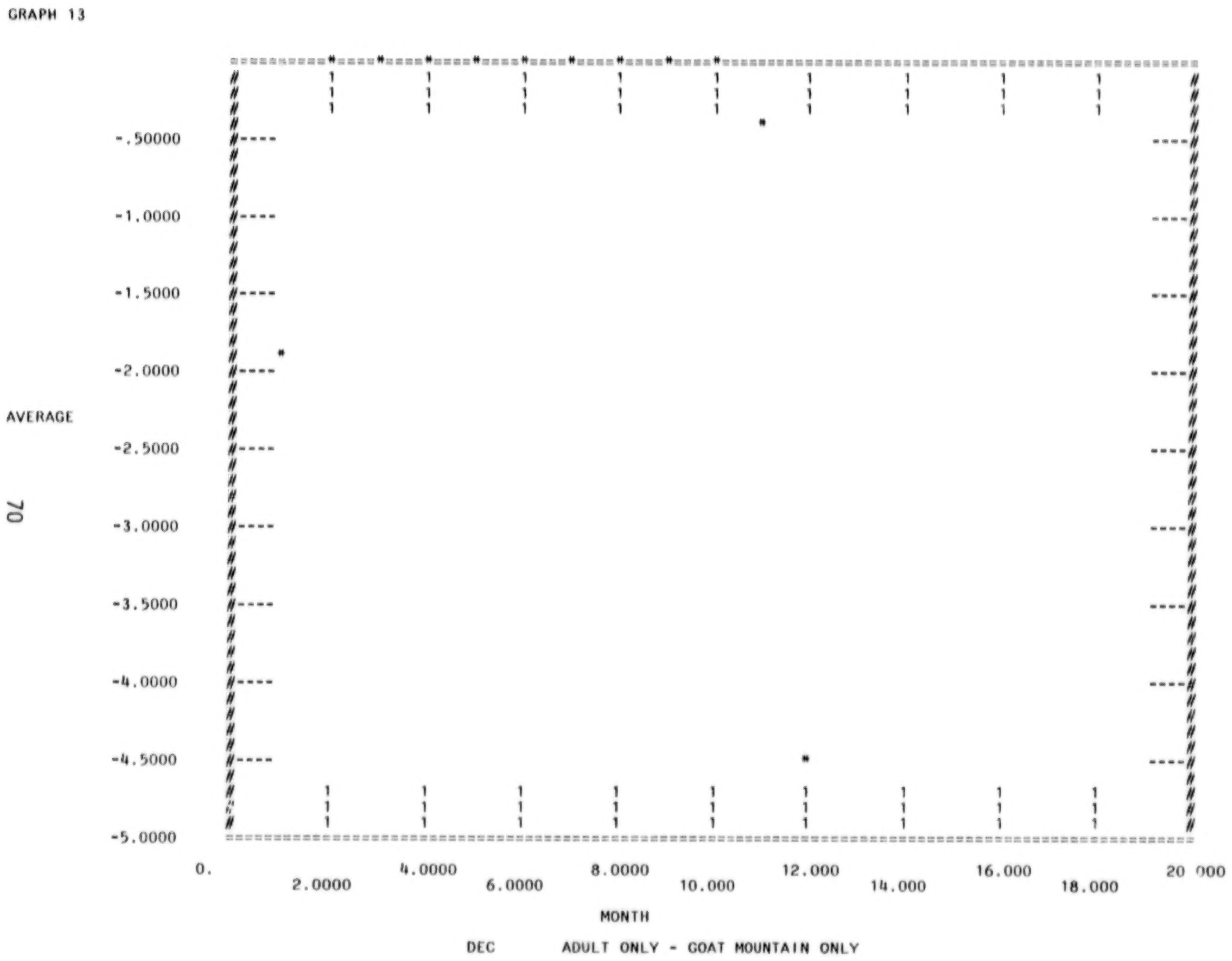

Figure 20. LPTDUR summary plot of percent change in mean adult habitat.

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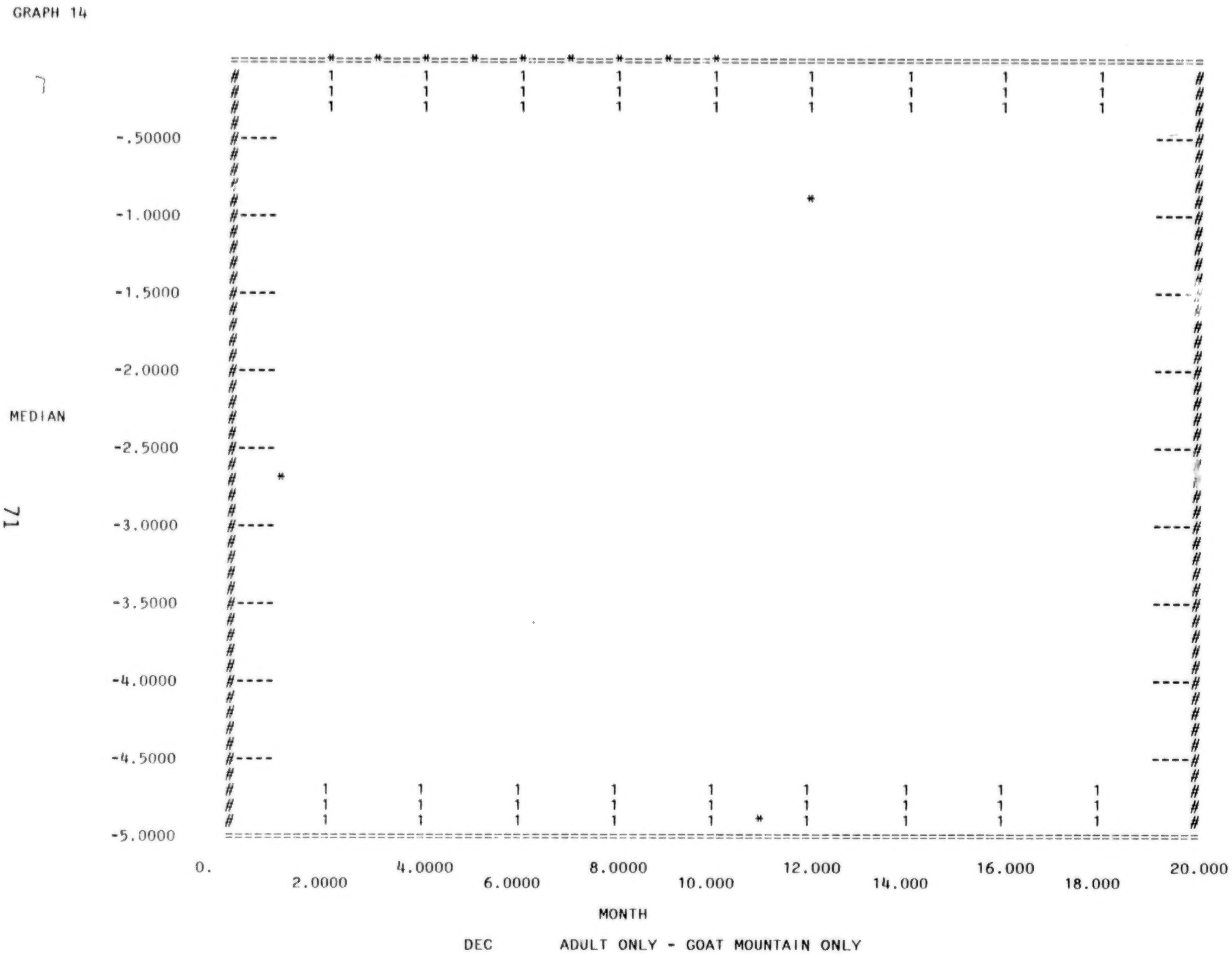

Figure 21. LPTDUR summary plot of percent change in median adult habitat.

```
DATE -  86/05/21.          TIME -  15.21.39.          PROGRAM - LPTDUR

        MONTH    CHANGE IN INDEX - A          CHANGE IN INDEX - B          CHANGE IN AVERAGE            CHANGE IN MEDIAN

        JAN                .00                          .00                         -1.94                        -2.73
        FEB                .00                          .00                           .00                          .00
        MARCH              .00                          .00                           .00                          .00
        APRIL              .00                          .00                           .00                          .00
        MAY                .00                          .00                           .00                          .00
        JUNE               .00                          .00                           .00                          .00
        JULY               .00                          .00                           .00                          .00
        AUG                .00                          .00                           .00                          .00
        SEPT               .00                          .00                           .00                          .00
        OCT                .00                          .00                           .00                          .00
        NOV                .00                          .00                          -.41                        -4.92
        DEC                .00                          .00                         -4.52                         -.89
```

Figure 22. LPTDUR summary table of percent changes in adult habitat.

```
            DATE -  86/05/21.          TIME -  13.26.54.          PROGRAM - LPTDUR


                      SUMMARY STATISTICS
                                                                                       PERCENT EXCEDENCE
MONTH                      AVERAGE                      MEDIAN                    INDEX - A                   INDEX - B
            CASE 0                CASE 2         CASE 0            CASE 2        CASE 0        CASE 2        CASE 0        CASE 2

JAN               .00                  .00             .00               .00          .00           .00           .00           .00

FEB              2.33                 2.50             .50               .50          .00           .00           .00           .00

MARCH           69.67                73.50           74.00             79.50          .00           .00           .00           .00

APRIL          239.33               272.33          249.50            291.50          .00           .00           .00           .00

MAY            465.33               607.67          456.50            626.00          .00           .00           .00           .00

JUNE           718.00               997.67          682.50            969.00          .00           .00           .00           .00

JULY          1140.67              1527.67         1088.00           1490.00          .00           .00           .00           .00

AUG           1577.17              2013.00         1545.50           2007.50          .00           .00           .00           .00

SEPT          1885.33              2337.50         1860.50           2342.00          .00           .00           .00           .00

OCT           2028.50              2485.50         2008.00           2494.50          .00           .00           .00           .00

NOV               .00                  .00             .00               .00          .00           .00           .00           .00

DEC               .00                  .00             .00               .00          .00           .00           .00           .00
```

Figure 23. LPTDUR summary statistics for degree-days.

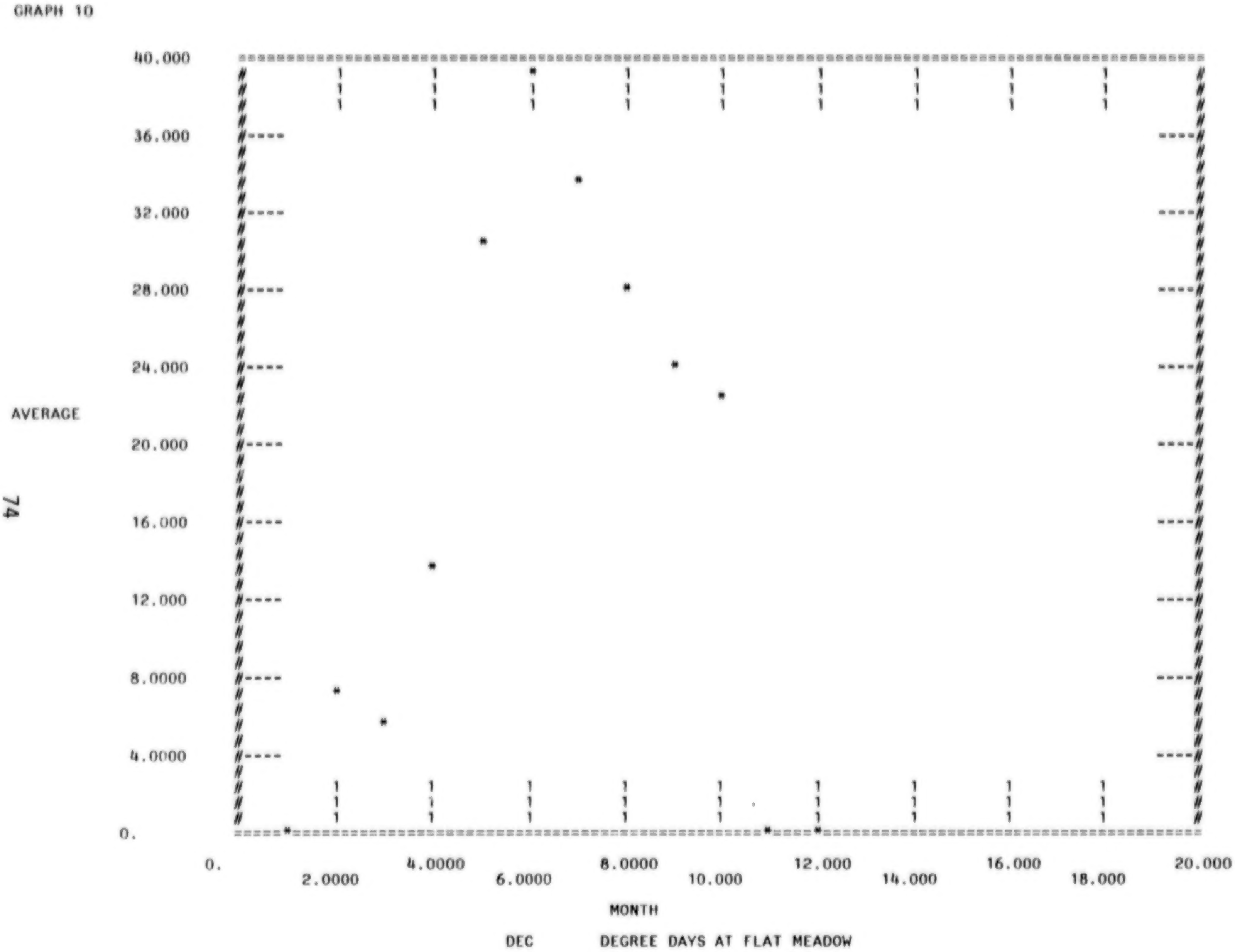

Figure 24. LPTDUR summary plot of percent change in mean degree-days.

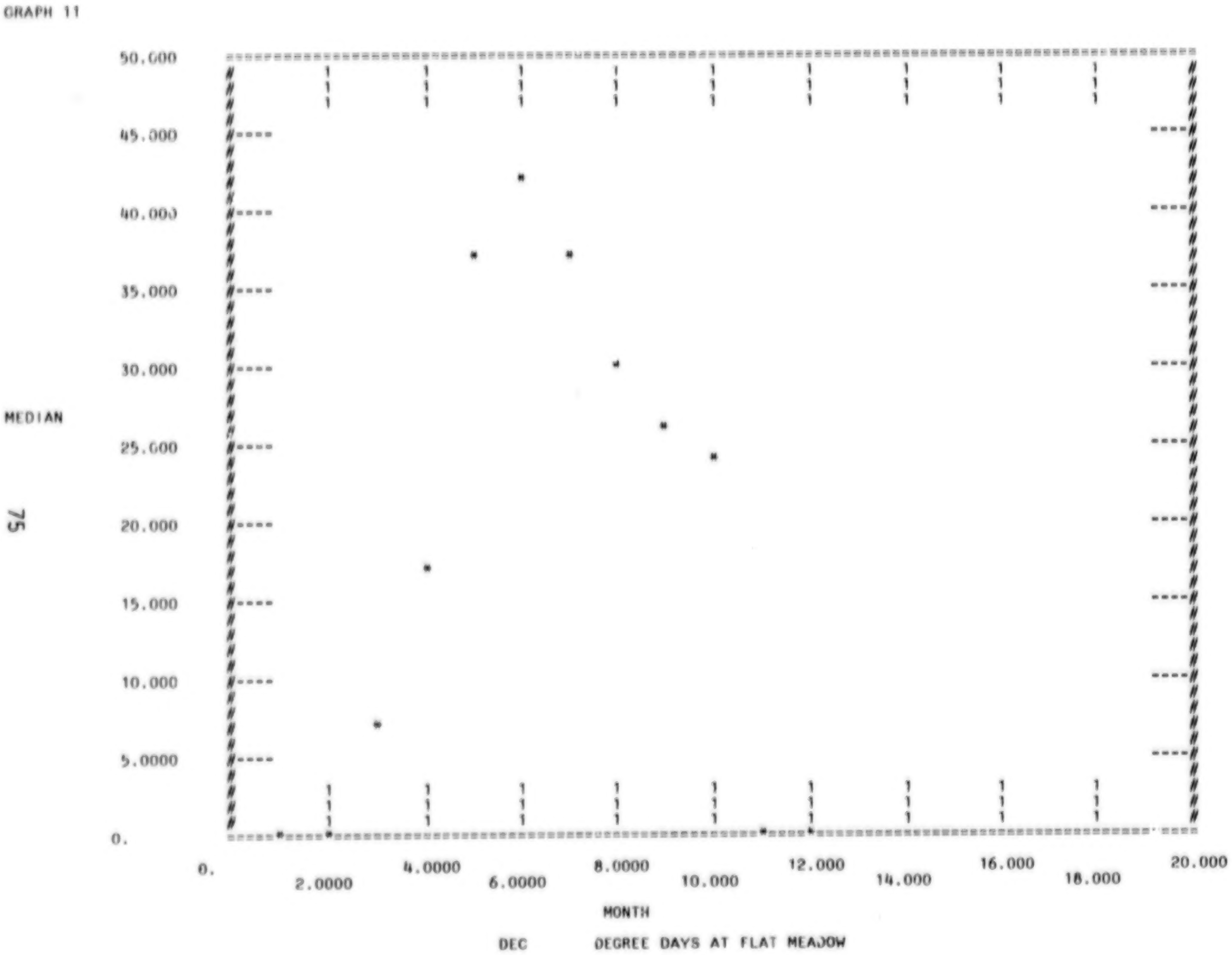

Figure 25. LPTDUR summary plot of percent change in median degree-days.

```
DATE -  86/05/21.          TIME -  13.26.54.          PROGRAM - LPTDUR

        MONTH    CHANGE IN INDEX - A        CHANGE IN INDEX - B        CHANGE IN AVERAGE          CHANGE IN MEDIAN

        JAN                  .00                        .00                      .00                       .00
        FEB                  .00                        .00                     7.14                       .00
        MARCH                .00                        .00                     5.50                      7.43
        APRIL                .00                        .00                    13.79                     16.83
        MAY                  .00                        .00                    30.59                     37.13
        JUNE                 .00                        .00                    38.95                     41.98
        JULY                 .00                        .00                    33.93                     36.95
        AUG                  .00                        .00                    27.63                     29.89
        SEPT                 .00                        .00                    23.98                     25.88
        OCT                  .00                        .00                    22.53                     24.23
        NOV                  .00                        .00                      .00                       .00
        DEC                  .00                        .00                      .00                       .00
```

Figure 26. LPTDUR summary of percent changes in degree-days.

Question 3. Where do basinwide changes in aggregate habitat values occur?

In this problem, habitat events were considered at only two sites, and the habitat types that occur at the two sites are exclusive of each other. Thus, the LNKT2H output will show 100% of the habitat for each life stage occurring at only one site. In a more complex network problem, the fraction of habitat at any site may change due to the effects of system management. Such shifts must be evaluated in terms of the species' accessibility to those areas. For this situation no changes in aggregate habitat location occur.

What to Recommend

Since the June mean and median degree-day values shift from below to above the 500 degree-day threshold, and since the later months also are above 500 because the values are accumulated, it appears that the drop in spawning area is the most significant change among the three habitat related variables evaluated. The degree-day increase will allow June to be a potential spawning month when the 20-degree minimum is exceeded. Under the proposed scenario, that threshold is exceeded in one year out of six (Figure 15). Thus, the best that can be hoped for is that the earlier accumulation of degree-days will ensure that spawning can occur in July in all years.

Degree-day accumulation is considerably improved under the proposed management scenario, but spawning habitat is dramatically decreased. The reduction in spawning areas seems to be more significant than the increase in degree-day accumulation. Since June seldom achieves sufficiently high temperatures for spawning under either scenario, July and August would appear to be good candidates for improving spawning habitat by adjusting the flow.

The July and August baseline flows ranged from about 90 to 450 cfs, whereas the proposed flows ranged from about 60 to 80 cfs. The habitat-flow relationship for bravefish spawning increases continuously over this range of flows; however, too much flow will decrease the degree-day accumulation. Under these circumstances and without further information about the life cycle needs of the bravefish, it may be best to attempt to maintain the low flows proposed by the project for February through May and provide the baseline flows during July and August. The following table (Table 14) summarizes the criteria that were examined to determine the flows to recommend to Big City.

From this table it is immediately clear that spawning is not possible in some years. If Big City could operate its project so flow in the spawning reach is within the range that is known to provide possible spawning conditions, it is less likely to encounter opposition. So minimum flows of 250 cfs for July and 100 cfs for August (the mean baseline flows for July and August in years when spawning was possible) are selected for testing as instream flow targets.

Table 14. Examination of multiple habitat criteria at the Flat Meadow spawning site for the spawning season under the baseline scenario.

Year	Degree-days accumulated Feb.-May	Month	Temperature (°C)	Spawning area (KSQFT)	Spawning possible this year
1980	516	June	11.2	0	Yes
		July	18.3	200	
		Aug.	22.7	219	
1981	362	June	13.2	0	No
		July	18.7	248	
		Aug.	18.7	225	
1982	575	June	14.1	0	Yes
		July	21.0	180	
		Aug.	20.5	204	
1983	546	June	16.7	0	Yes
		July	19.0	247	
		Aug.	20.1	209	
1984	396	June	10.7	0	No
		July	18.0	225	
		Aug.	20.2	252	
1985	397	June	9.2	0	No
		July	15.2	444	
		Aug.	16.1	310	

These flows must be tested by asking the consultant's hydrologist to run the HYDROSS model a minimum of two times. The first run is to have those minimum flows satisfied as the highest priority water use, i.e., at the project's expense. The second run is to have the instream flow priority set below the project's priority and only to be met without affecting Big City.

The results of these two new scenarios will reveal several bits of information. The first run will show the amount of spawning habitat that is available with the selected minimum flows (to the extent the reservoir can support that flow). This will also give a clearer picture of the degree-day and spawning habitat tradeoff. It will also show the impact on Big City's operation of meeting that instream flow. The second run will show how often those minimum flows can be met when Big City's diversion has priority. The habitat that results will reflect the conditions that may occur if Big City's water right is considered to have precedence over the bravefish.

From Figure 12 it is clear that there will be a conflict between supplying 97 KDAM3 of water to Big City and providing releases for instream flows. This is apparent because the Sunlight Reservoir just recovers to initial storage levels after having been drawn down during the dry year cycle. Any further requirements for drawing water from it will result in the reservoir going empty and both Big City and the instream flow being missed at some point. Operation of the reservoir at Big City's expense will determine the amount Big City's water supply will have to be curtailed to meet the instream flow recommendation.

This ends one iteration of the analysis. It can be assumed that there will be further iterations as the models are used to further define the effects of various proposed operations. The network habitat analyst should derive a family of instream flow regimes that will provide specific amounts of spawning habitat for the bravefish for each diversion of water out of the basin. One possible form of display that may be useful for this analysis is a median spawning habitat versus annual diverted volume relationship derived from trying several levels of instream flow for habitat. Such a relationship should provide decisionmakers on both sides valuable information from which to negotiate a final project operations plan.

Due to the paucity of information about the bravefish it may be wise to ask Big City to consider funding a study to help remove the uncertainty faced in dealing with this little understood fish. The modeling process described above can be used to identify those portions of the fish's life cycle where additional information could lead to greater management certainty. Past experience suggests it is wise to avoid use of such studies as a means of preventing water resource development. The credibility and influence of the resource agency involved often suffers and no real resolution to the problem is achieved. Rigid study targets and deadlines should be established as a means of ensuring results and lowering resistance among those who would oppose studies altogether.

5.5 CONCLUSION

In developing this example, several compromises between length, complexity, and completeness were made. In a more general situation, where flow and temperature recommendations at several sites within a network will be required, a considerable amount of time must be devoted to testing the recommendations by looping through the iterative procedure sketched above. Due to the uniqueness of each network habitat problem, it does not appear possible to develop an automated method of identifying which shifts in amount and location of habitat will be either a detriment or enhancement to the fish population. Network problems are likely to require copious amounts of judgment as well as data for the foreseeable future.

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APPENDICES

USING IFG'S NETWORK HABITAT ANALYSIS TOOLS

The Instream Flow Group has developed a set of programs for network habitat analysis that deal with a specific set of conditions. As of the date of this document, programs for steady-state, monthly time-increment analysis are available. Programs for nonsteady-state or different time step analyses will be developed as the demand arises. Prior to applying the computer program tools documented in the appendices, the following preliminary steps must have been performed:

1. A problem scoping exercise (in which all parties to the environmental issue being considered have participated) has been completed. In this scoping effort, one must have defined: (1) the degree of detail required to satisfy the involved parties that necessary issues have been accurately addressed; (2) the geographic scope of the analysis, species, and life stages of concern; (3) the habitat index to be used; and (4) the management options and impacts. In addition, the level of significance must be defined; that is, the amount of change from a baseline habitat condition that is considered detectable and important must be selected (e.g., 20% shift in mean habitat, increase in frequency of occurrence of habitat less than a specified amount, or other criteria). The network habitat analysis can be best performed when these boundaries have been established.

2. The necessary microhabitat analyses (to provide some form of habitat index flow relationship for needed points in the network) have been performed. This index can be taken from any one of many such indices that have been proposed; for example, wetted perimeter or top width type methods. If multiple life stages or species are to be considered, the index must be able to distinguish among them; for example, weighted usable area applied to several life stages. If weighted usable area or another index that requires species suitability criteria as an input is applied, the background analysis must include development of those criteria. The index must consider species phenology if a succession of life stages (adult, spawning, fry) is likely to be affected by water management alternatives.

3. The necessary macrohabitat variable analyses (to provide macrohabitat values at all points in the stream network) have been planned for as part of the study, or already performed. This step may include temperature modeling and monitoring or modeling of water quality constituents.

4. Preliminary water management options have been generated (to provide the basis for the basinwide habitat response descriptions to be generated). This step should include generation of a baseline water management scenario and alternative project configurations or operations using a water system operation model.

Assuming the following information is available as a result of these preliminary steps, the network habitat analysis tools can be applied. Data assumed available:

1. Flow and optional temperature time series for all habitat sites in the network. We strongly recommend that at least 10 years of records be analyzed.
2. Habitat/flow relationships for all sites and life stages of interest.
3. Temperature suitability criteria for all life stages of interest (optional).

PERFORMING THE ANALYSIS

Initial Steps

1. Run LNKT2H and LNKT2TS (or LNKQ2H if temperature is not a consideration) for all life stages (there will only be one "life stage" if a wetted perimeter analysis has been performed).
    a. Aggregate each life stage of each population into a single basinwide habitat time series. The linking program LNKT2H facilitates this aggregation by summing across locations you choose for each life stage.
    b. Aggregate across any subsets of any life stage that appear to be important; for example, if there is a migration blockage, aggregate the habitat available on each side of the blockage.
    c. Carefully check the output file from each linkage run for error messages, strange values (too large, too small, wrong place in the network), i.e., anything that might indicate errors on your part.
2. Run a time series plot program from the IFG time series analysis library (TSLIB) for each time series file or combination of time series files that seems appropriate. Be sure that at least the aggregate time series are plotted. Check the output for possible errors.
3. Run a duration plot program from the IFG time series analysis library (TSLIB) for each time series derived above for the baseline condition and each water management option scenario to be considered. Program LPTDUR has been used for this example. Check the output for possible errors.

QUESTIONS TO BE ANSWERED USING THE RESULTS OF THESE STEPS

These general questions may apply to many types of analyses of instream flow issues. The relationship to network habitat analysis is discussed with each question. The numbers associated with each question are assigned for convenience only and do not imply priority.

1. Is there a sufficient number and frequency of long-term life cycle events in the basin?

In essence, this step is no different from what would be done for a single stream segment analysis. The only difference is that the question is being asked for the sum of life stage events across the basin.

What to look for:

The time series of aggregate habitat values for a given life stage will give an indication of annual frequency of necessary habitat events. For example, consider a baseline scenario under which there are no periods of insufficient (less than the 80th percentile exceedence) spawning habitat in excess of one year (i.e., the greatest gap in adequate spawning potential is one year). If the proposed scenario causes the same low spawning habitat events to occur with continuous spans of two or three (or more) years, an impact that cannot be measured by the exceedence statistic alone must be considered. In this situation, the continuous viability of the species may be in doubt even though the summary statistics show little change. The significance of "gaps," however, depends on the life history of the species under consideration.

2. When do basinwide changes in aggregate habitat values occur?

What to look at:

Look at the aggregate monthly summary statistics and summary graphs at the end of the LPTDUR output for mean, median, index A, and index B values. The summary statistics can be interpreted as follows:

Index A

This index focuses on "bad" times (the values below the 50th percentile). This index can be used for habitat preservation as in an endangered species type problem, where a few extreme events could eliminate the population.

Index B

This index ignores extremes (how are things between the high and low extremes). If the low habitat events in a widely variable habitat time series do not decimate the population, this index reflects the middle range of usable habitat values under conditions of erratic variation.

Median

The median represents a "typical value" since it is the 50% exceedence value. One might focus on the median if interested in maintenance of habitat magnitude or frequency of occurrence.

Mean

The mean contains overall averages by month, incorporating extremes. A shift in the mean indicates either a shift in the overall level of the process or a change in extreme, possibly catastrophic, events (look at the duration curve for that month for more detail).

What to look for:

Using the summary graphs from LPTDUR check the deviation in indexes A or B, mean or median values from month to month. If either mean or median shows a large percent deviation in any month, the whole basin's habitat has changed by that percentage deviation and further investigation is indicated. Since this may be the result of a residual (and therefore trivial) amount of habitat being changed by a large percent you should look at the summary statistic values to determine the actual habitat magnitudes involved.

3. Where do basinwide changes in aggregate habitat values occur?

What to look at:

To determine if there is a systematic shift in the distribution of habitat in a basin as the result of project actions, check the site distribution summary in the LNKQ2H output report (immediately following "BEGIN THE REPORT SECTION"). These percentages show the distribution of habitat among the sites in the basin for the base condition and proposed condition. Comparing these values will indicate if there is a dramatic and systematic shift among sites.

What to look for:

For any one life stage, such a shift may or may not be significant; however, the distribution percentages among life stages should also be compared. The analyst must decide if inconsistent percentage shifts between life stages are detrimental or enhance overall habitat worth for the basin. For example, the following habitat distribution changes may improve habitat viability:

	Spawning		Rearing	
	Baseline	Proposed	Baseline	Proposed
Site A	8%	11%	12%	8%
Site B	12%	10%	15%	7%
Site C	50%	41%	18%	52%
Site D	30%	38%	55%	33%
	100%	100%	100%	100%

Under baseline conditions, the majority of spawning habitat is at sites C and D while the majority of rearing habitat is at site D. Effectively, this may limit the utility of site C to the species due to the reduced relative amount of rearing habitat. Under proposed conditions the relative percentage distribution of spawning and rearing habit is more consistent among all sites. Provided the magnitude of habitat at these sites has not been reduced and other necessary life cycle needs are met, the proposed condition represents a potential enhancement of habitat in this basin.

WHEN TO DISAGGREGATE

The questions asked above were all applied to the basinwide aggregate time series of habitat values for each life stage evaluated. As a result, the conclusions that may be drawn are based on aggregate summary effects. In many situations, this will be sufficient to evaluate the merits of alternative water management scenarios and to compare the habitat that results from such scenarios with the baseline condition. In other cases, however, it may be appropriate to divide the analysis to pick up important aspects of the system being studied.

At least three key considerations for subdividing the habitat analysis are known. They are the need for degree-day analysis, stratification of the population, and the existence of critical conditions. These considerations are dealt with below.

When the accumulation of degree-days is an important part of the analysis, it makes little sense to sum total basinwide degree-days. Degree-days must be evaluated over the reach of the river where the fish that require the degree-day accumulation will be at the time of the year when that thermal stimulus is needed. Portions of the network that otherwise have adequate habitat may not be usable for some activities, such as spawning, if the needed number of degree-days has not occurred.

Populations of the same species may be treated separately if the distance between them is large enough to preclude regular migration, if there is some blockage to migration, or if they are known to be isolated for other reasons. Subaggregation of habitat over the portion of the network where a particular population is known to range allows each population to be evaluated and the tradeoffs between those populations to be explored.

Critical habitat areas may be isolated from the basinwide aggregate for special analytical attention. In an endangered species analysis in the Colorado River Basin, certain areas are known to be the sites of critical life cycle events for the Colorado River squawfish. The analysts working on that problem have concluded that those critical areas must be evaluated separately from the basinwide aggregate due to their importance for the continued survival of the species.

When disaggregation is considered, the same steps and questions described above apply. Due to the sheer volume of numbers that are generated when several time series are analyzed, it is suggested that the analyst strive to define the smallest set of life stage variables required for the analysis and avoid disaggregation when possible.

APPENDIX A

TITLE -- LNKQ2T (Flow Model to Temperature Model) Version 1.3

AUTHOR -- Terry Waddle and John Bartholow
Instream Flow & Aquatic Systems Group
U.S. Fish & Wildlife Service
Western Energy and Land Use Team
April 1985

1.0 INTRODUCTION

This program provides a linkage between a steady-state, monthly reservoir and river network operations planning model, HYDROSS (U.S. Bureau of Reclamation, Upper Missouri Region), and the Instream Water Temperature Model, referred to here as SNTEMP (Stream Network Temperature Model), developed at the Cooperative Instream Flow Service Group, U.S. Fish and Wildlife Service, by Dr. Fred Theurer while on detail from the U.S. Soil Conservation Service (Theurer et al. 1984).

This linkage will replace the flows from the SNTEMP hydrology data file with flows generated by HYDROSS and produce a new updated hydrology data file. This file may then be used in what-if type temperature evaluations of various water management scenarios that have been simulated using HYDROSS.

This program is a member of a family of programs designed to facilitate networkwide habitat analysis. This group consists of:

LNKQ2T - HYDROSS to TEMPERATURE MODEL (this program)
LNKT2H - TEMPERATURE MODEL to HABITAT MODEL
LNKQ2H - HYDROSS to HABITAT MODEL
LNKG2H - GAGE DATA to HABITAT MODEL
LNKT2TS - TEMPERATURE MODEL to TEMPERATURE and FLOW TIME SERIES

For consistency, documentation of programs in this family will refer to HYDROSS control points as stations, the temperature model control points as nodes, and areas of habitat interest (where PHABSIM or other physical habitat indices have been applied) as sites.

The general outline of this program allows most monthly river system planning models or monthly-time-increment hydrology models to be linked to the SNTEMP model. Each linkage will require rewriting the routines FLOINIT and FLOGET to accommodate the individual stream network model's particular output characteristics, the error checking portions of subroutine TMPINIT related to the HYDROSS model, and water year conversion conventions throughout.

1.1 Assumptions

This linkage depends on three initial assumptions about organization of the data used for input to HYDROSS and SNTEMP. First, it is assumed that base data have been prepared and SNTEMP has been calibrated to historic conditions for the river basin to be studied. Second, it is assumed that the user is familiar with both models and is able to implement a HYDROSS river network that contains the water movement elements necessary to match the SNTEMP network. Third, it is assumed that reservoir release temperatures will be manually inserted in the modified SNTEMP hydrology data file produced by this program after the linkage has been run. Implicit in the second assumption is the condition that all unregulated headwaters have been set up such that the flow model, e.g. HYDROSS, will produce flows that geographically correspond to the gage records at those headwaters. Otherwise there is a logical inconsistency in using the same headwater temperature.

These assumptions imply the following sequence of actions when a study is being made:

(1) Prepare all data files and calibrate SNTEMP (Theurer et al. 1984).

(2) Organize the HYDROSS model network so each water movement component, i.e., headwater, confluence, diversion, return flow, structure, etc., in the SNTEMP network is represented.

(3) Prepare all data files and execute HYDROSS for the water management scenario of interest (Waddle in prep.).

(4) Modify the SNTEMP hydrology node file to include the required linking information (see Section 3.3.3).

(5) Run this linking program.

(6) Rerun SNTEMP using your revised hydrology data file (generic name L1HUP) to obtain the stream temperature results of the simulated operation scenario.

(7) Proceed with further analysis such as habitat response to the scenario flow and temperature regimes.

(8) Repeat steps 3 - 7 in a "gaming" loop as required.

2.0 EXECUTION

2.1 Conventions

A major difference between this linkage program and others in the network habitat analysis family is the manner in which file names are processed. When using LNKQ2T the study-specific procedure file described below may contain file names that pertain to the study at hand. That is, you do not have to rename any of your files to specific names. Rather, you can (and should) preserve the file names related to the study you are performing. This is particularly useful because of the manner in which HYDROSS defines its output file name. The file names used in this documentation are supplied as examples. It is suggested that you retain the suffixes used in these examples but substitute your own prefixes. For example: L1JCF could be SACJCF for a study on the "Sacramento" river.

Usually it is best to XEDIT your job control file (L1JCF, see below) to select the desired options for a particular linkage run, then "GET" your files by using a CDC procedure file.

2.2 Procedure Files

The following illustration of procedure files shows a study-specific procedure file that gets the needed files and the generic procedure it calls to run the linkage.

```
.PROC,PSTUDY.          - study specific procedure file
*                        change procfil name and file names to suit the
*                        different cases you may run
*                        i.e., PSTUDY1, PSTUDY2 .... etc.
GET,PSNH/UN=IFGuser.   - name of stream habitat analysis procedure file
*                        located on user number IFGuser.
*
BEGIN,RLNKQ2T,PSNH,L1JCL,L1JOB,L1HDR,L1HYD,L1HUP,HYDOUT.
REVERT. STUDY LINK Q2T COMPLETE SEE FILE MESSGS
EXIT.
REVERT,ABORT. LINKAGE FAILED SEE FILE MESSGS
```

The account name "IFGuser" will be different on each computer system. Contact IFG for this name on the system you will be using.

2.3 Batch Processing

The following illustration of a batch job shows how the needed procedures can be called within one job. When using batch processing, be sure that the permanent file L1JCF includes the option selections you desire. This means you should "XEDIT" L1JCF, set your options, and save or replace it before submitting the job. Note: you should also prepare separate study-specific batch jobs for several cases you may run like the procedures for separate cases cited above.

The following is an example of a batch job for a specific study. Remember, you will substitute your study names for L1... and HYDOUT.

```
/JOB
STUDY1.
/USER
CHARGE,*.
GET,PSNH/UN=IFGuser. - PSNH is located on IFGuser
BEGIN,RLNKQ2T,PSNH,L1JCF,L1JOB,L1HDR,L1HYD,HYDOUT,L1HUP.
SKIP,END1.
EXIT. -  error exit - if something goes wrong continue here
ENDIF,END1.  - skip to here so last operations always performed
REWIND,*.  - rewind all files
COPYBR,OUTPUT,L1REC/NA.
COPYBR,MESSGS,L1REC/NA.
REPLACE,L1HUP/.
DAYFILE,L1REC.
REPLACE,L1REC.
```

File L1REC should be checked before proceeding with any subsequent steps, such as running SNTEMP, because all error messages will now be stored there.

3.0 APPLICATION

3.1 Description of logic

LNKQ2T uses several files. The file names are supplied by the user in the study-specific procedure file described above. The remainder of this documentation uses generic file names for simplicity; however, in actual use any names that aid in organizing study data may be used. It is suggested that prefixes, such as "SN..." for the "Snake River" followed by "..JCF" or "..HDR", etc. from the generic file names be used to differentiate between studies and retain file identity. From a user's perspective, LNKQ2T does these things:

3.1.1 Opens and rewinds all files necessary for operation:

Input:

- L1JCF - Linkage job control file, must be local
- L1JOB - SNTEMP job control file from calibration run, must be local
- L1HDR - Hydrology node linking file, must be local
- L1HYD - Hydrology data file from SNTEMP calibration run, must be local
- HYDOUT - HYDROSS binary output file, must be local

Output:

- OUTPUT - For brief program termination messages
- MESSGS - For run status, error messages and summary report. This file is also rewound at the end of the run.
- L1HUP - The new "updated" hydrology data file to be used by a subsequent SNTEMP run for evaluating temperature effects of operation scenarios

3.1.2 Reads the job control data file (L1JCF) for linkage run study title, normal (mean) data flags, and beginning month of year type used.

3.1.3 Reads the SNTEMP job control file (L1JOB) to get the original time span of the temperature model data set.

3.1.4 Reads the hydrology node data file to determine which HYDROSS stations are needed. Data file is checked for proper syntax. See warning and fatal error messages in Section 6.0 below.

3.1.5 Reads HYDROSS output to get linking flows. HYDROSS output is checked to ensure that HYDROSS and SNTEMP networks are really compatible. See Section 6.0 for error messages.

3.1.6 Reads the original hydrology data file L1HYD and writes a new hydrology data file L1HUP that contains the original L1HYD stream temperatures and revised flows for each node.

3.1.7 Writes a summary report (MESSGS) for each stage of processing that includes all warning and fatal error messages and indicates if the program run was successful.

3.2 Linkage Options

The primary options for this program are controlled by the job control data file (L1JCF). Through the proper use of this file, you may select options that tell the program: (a) if normals (average flow and temperature values for the period of the study) occur in the original hydrology data file L1HYD, (b) if normals are also desired in the revised hydrology data file L1HUP, and (c) if the hydrology data files are in calendar or water year order. This last option is selected by supplying an offset value indicating the first month of the noncalendar year. For example: enter 10 for October, the beginning of the traditional water year, 4 for a water year that begins in April, but 0 (or blank) for the standard calendar year.

3.3 Description of Input Files

3.3.1 L1JCF -- Job Control File, formatted

The job control file is used to control the overall execution of this program. Description of L1JCF:

Line 1 is a title line; all 80 columns may be used. It is recommended that you put critical descriptive information here, including source and date of driving data.

Line 2 contains the beginning and ending year span you desire to be generated by the linkage.

column	entry
1	NORM1 - 0 = no normals in SNTEMP data file L1HYD 1 = there are normals in L1HYD
2	NORM2 - 0 = do not create normals in file L1HUP 1 = create normals in L1HUP
3	IABR - 0 = Default month name abbreviations used in SNTEMP files. 1 = User supplies month name abbreviations in lines 4 and 5

Line 3 contains the starting month of the year in a right-justified integer field.

4-5	0 for calendar year 10 for traditional water year, etc.

The next two lines are supplied if IABR is set to 1 in line 2. Lines 4 and 5 contain month abbreviations, 6 months per line in 6A8 per line. Fill the eight characters exactly as abbreviations appear in the SNTEMP hydrology data file. The default month abbreviations are:

(Column numbers shown for reference)

```
         1         2         3         4
123456789012345678901234567890123456789012345678
     JAN     FEB   MARCH  APRIL      MAY    JUNE
    JULY  AUGUST    SEPT     OCT     NOV     DEC
```

The last line in the file contains the format of the year field in the SNTEMP hydrology data file. In the example shown below, the year is a four digit year and is right justified. If the year field in the hydrology data file appears as 1959-60 (right justified) use a format of (6XI2).

An example of the job control file follows:

```
TEST OF HYDROSS - TEMP. MODEL LINKAGE USING GREEN/YAMPA DEMO FILES JUNE 1984
111
  10
JAN     FEB     MAR     APR     MAY     JUN
JUL     AUG     SEP     OCT     NOV     DEC
(4X,I4)
```

In this example, the user has indicated that normals (means) occur in the SNTEMP hydrology data file and that they should be provided in the revised hydrology data. The linkage is directed to perform a conversion to water year-ordered data starting in month 10 (OCT). User-supplied month abbreviations are included because they differ from the default, and the year field in the hydrology data file is four digit, right justified.

3.3.2 L1JOB - SNTEMP job control file, formatted

This file is described in detail in Theurer et al. (1984). The linkage program uses it to determine the number of SNTEMP hydrology nodes and the beginning year of temperature model data and the total number of years of such data.

An example of an SNTEMP job control file follows:

```
JOB CONTROL FILE: UPPER COLORADO RIVER BASIN--VERIFICATION DATA SET
TEMPERATURE MODEL COMPUTER PROGRAM VERIFICATION DATA SET
FFFFFFFFFFTFFFFFFFFF                                    FFFFTFFFFFFFFFFFFFFFFFFTTF
     23.      1.   1960.     12.      0.     20.     12.     11.      0.      0.
      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
      0.      0.      0.      0.      1.      1.     24.      1.     12.      0.
    0.00  0.0000    0.00  0.0000    0.00  0.0000    0.00  0.0000    0.00  0.0000
    0.00  0.0000    0.00  0.0000    0.00  0.0000    0.00  0.0000    0.00  0.0000
    0.00  0.0000    0.00  0.0000    0.00  0.0000    0.00  0.0000    0.00  0.0000
KVRFTME         KVRFMET         KVRFSKL         KVRFSTR         KVRFSTD
KVRFHDR         KVRFHYD         KVRFSHD
```

NOTE: entering the starting year (1960) will only work in the temperature model L1JOB file if yearly data in SNTEMP are indicated by "standard" calendar years. If this is not the case, you need to make a duplicate L1JOB file with the starting year included as shown. Without the starting year expressed as 19.., this linkage will fail.

3.3.3 L1HDR - Hydrology Node Linking File, formatted

The SNTEMP hydrology node file is also the linkage direction file. This is the most important file in the linkage process. Great care should be exercised in its preparation. The user is expected to recognize what elements of each model do and do not match, so only you can ensure that relevant information is passed from HYDROSS to SNTEMP by organizing this file carefully.

The file L1HDR contains the hydrology network information for the SNTEMP model and the linking information to the river network model HYDROSS. The same file may (and should) be used for both SNTEMP and this linkage program. This linkage requires that the hydrology node file have records inserted to indicate which HYDROSS model information is to be matched to which SNTEMP model node. Up to nine matching records may be read from the SNTEMP model hydrology node file. Each record contains the flow model station number, 4 fields of matching information (some of which may not be used), and up to 56 columns of descriptive information for the linked station. SNTEMP nodes are thus set up with pointers to HYDROSS stations.

Note that proper use of the hydrology node linking file will enable you to link more than one node to a single HYDROSS station or to a group of stations. That is, the cross referencing is completely flexible so any SNTEMP node may refer to any HYDROSS station. In this way, several temperature nodes that have the same reach flow as seen by HYDROSS at a single control point may extract that flow. The following figure shows the same network represented in HYDROSS and SNTEMP.

```
 HYDROSS                       SNTEMP

   |     /                   H *       * H
   |    *  061510                |      /
   |   /                       | T   /
   *---    061750            B **----
  /|                           * J
 / |                           * D - two diversions
.  |                         //|     from same point
.  |                        .. |
.  |                        .. |
 \ |                        . \|
   *       061790            . * R1
                              \|
                               * R2
```

To represent these networks, the linking information would be arranged as follows:

to link SNTEMP main stem Headwater flow,
  take 061750 inflow;

to link SNTEMP main stem Branch flow,
  take 061750 outflow (as no other activity intervenes);

to link SNTEMP tributary Headwater flow,
  take 061510 inflow;

to link SNTEMP tributary Terminus flow,
  take 061510 outflow,

to link SNTEMP main stem Diversion flow,
  take 061750 diversion flow,

to link SNTEMP main stem Return flows,
  associate appropriate return flow type with R1 and R2.

It is possible for the SNTEMP network to extend further upstream than the HYDROSS network. This linkage will merely pass the flow and temperature values at all unlinked nodes through to the updated hydrology data file.

General description of example linkage file:

- Column 19 of each SNTEMP hydrology node record indicates the number of linking records to follow. SNTEMP J nodes do not require and are not permitted to have linking records. All other hydrology nodes may be assigned linking records.
- Each linking record contains information that corresponds to the SNTEMP hydrology node.
- When more than one station record from the flow model is associated with an SNTEMP hydrology node; it is assumed that those values are summed. That is, if three return flows are linked to a single point their effect is summed before passing to the updated hydrology data file. If they arrive at three separate points they should be represented in the hydrology node linkage file as three separate temperature nodes.

- For interfacing to HYDROSS the linking record format is:

  Record 1 - See Theurer et al. (1984) for details

  Record 2 - Matching records (up to 9 possible per SNTEMP node)

Column	Format	Contents
1-2	blank	
3-8	a6	6 digit station identification
9	blank	
10-12	a3	linking information type to be extracted from HYDROSS station as follows: station inflow - IN station outflow - OUT diversion from station - DIV return flow to station - RF
13-15	i3	diversion number, i.e., 005 for D005 or return flow type as " 4" , " 2" etc. Please refer to HYDROSS Users' manual for details
16	blank	
17-19	a4	additional linking information as needed DIV - diversion for a return flow's source OUT - station outflow for structures blank for all others
20-22	a3	diversion number reference for a return flow node, i.e., 005 indicates source diversion was D005, blank for all others

Repeat sets of records 1 - SNTEMP hydrology node, and 2 - matching HYDROSS station until the network is covered. Remember to omit matching records for a type J node.

A summary of the syntax checks performed on this data file follows:

--- at an 'H' headwater, test for presence of IN or OUT
--- at a 'D' diversion, test for presence of DIV and div #
--- at an 'R' return flow, test for presence of RF and rf type then DIV and div #
--- at an 'S' structure, test for presence of OUT
--- at a 'B' branch, test for presence of OUT
--- at a 'J' junction, test for presence of no link data allowed
--- at a 'T' terminus, test for presence of OUT
--- at the 'E' end node, test for presence of OUT
--- at a 'Q' node, test for presence of IN or OUT
--- at a 'P' point source node, test for presence of RF or OTH
--- at a 'V' verification node, test for presence of IN or OUT
--- at a 'C' calibration node, test for presence of IN or OUT

When these checks are unsatisfied, fatal errors are reported in file MESSGS immediately after the record that produced the error. Error messages are summarized in Section 6.0.

An example of a hydrology node linkage file follows:

```
HYDROLOGY NODE FILE: UPPER COLORADO RIVER BASIN--VERIFICATION DATA SET
GREEN RIVER     S 1S2       661.3 FLAMING GORGE DAM
  234500 OUT                       GREEN RIVER FLAMING GORGE RES
GREEN RIVER     B 1         556.7 YAMPA RIVER CONFLUENCE
  240010 OUT                      GREEN RIVER ABOVE YAMPA CONFLUENCE
YAMPA  RIVER    S 1         681.5 MAYBELL/JUNIPER DAMSITE HEADWATER STRUCTURE
  251000 OUT                      YAMPA R. AT JUNIPER SPRINGS DAMSITE
YAMPA RIVER     S 1 5       652.0 CROSS MOUNTAIN S NODE
  252000 IN      OUT              YAMPA RIVER AT X-MT DAMSITE IN/OUT REQ'D
YAMPA RIVER     B 1         638.8 LITTLE SNAKE CONFLUENCE
  259010 OUT                      YAMPA R. ABOVE LITTLE SNAKE CONFLUENCE
LITTLE SNAKE    H 1         651.6 LILY GAGE
  260000 OUT                      L. SNAKE RIVER AT MOUTH
LITTLE SNAKE    T 1         638.8 YAMPA CONFLUENCE
  260000 OUT                       L. SNAKE R. AT MOUTH
YAMPA RIVER     J           638.8 LITTLE SNAKE JUNCTION NO MATCH RECORDS
YAMPA RIVER     T 1         556.7 GREEN RIVER CONFLUENCE
  260099 OUT                      YAMPA RIVER AT MOUTH
GREEN RIVER     J           556.7 YAMPA RIVER JUNCTION
GREEN RIVER     D 1         503.6 DIVERSIONS ABOVE JENSEN - VERNAL WATER USERS
  260150 DIV002                   HYDROSS VERNAL WATER USERS DIVERSION
GREEN RIVER     V 1S        485.9 JENSEN GAGE
  261000 OUT                      GREEN RIVER NEAR JENSEN UT.
GREEN RIVER     R 1         422.3 RETURN FLOWS AT VERNAL DRAIN
  261000 RF    4 DIV002           RETURN FROM HYDROSS DIV D002
GREEN RIVER     E 1         399.0 DUCHESNE RIVER CONFLUENCE
  261099 OUT                      GREEN ABOVE DUCHESNE CONFLUENCE
```

3.3.4 L1HYD -- SNTEMP hydrology data file

The SNTEMP hydrology data file contains flow and temperature data for each node in the temperature model network. The linkage reads through it to determine which months of the year have been used for temperature simulation (not all 12 are required for SNTEMP) and which temperature values are known (such as at headwaters). The relevant temperature information is transferred to file L1HUP. See Theurer et al. (1984) for the format of this file. A truncated example of the hydrology data file is given below for reference.

```
HYDROLOGY DATA SET FILE: UPPER COLORADO RIVER BASIN--VERIFICATION DATA SET

GREEN RIVER      S 1S2       661.3 FLAMING GORGE DAM
 1959-60     OCT  31.170
             NOV  24.110            - note missing temperature data is
             DEC  17.180              filled in by the SNTEMP regression
             JAN  12.060              routine
             FEB  14.160
           MARCH  68.500      2.67  -  headwater and structure
           APRIL  66.720      9.55     nodes include temperature
             MAY  58.290     12.50     data
            JUNE 103.010     17.55
            JULY  35.740     20.50
          AUGUST  19.830     19.00
            SEPT  16.590     16.64
 1960-61     OCT  22.510      8.17
             NOV  25.720      1.21
             DEC  12.320
             JAN  12.470      0.51
             FEB  13.840      1.04
                .
                .
                .
                .
            SEPT  51.930      9.83
GREEN RIVER      B           556.7 YAMPA RIVER CONFLUENCE
 1959-60     OCT  31.695
             NOV  25.774
             DEC  15.636
             JAN  13.063
             FEB  15.213
           MARCH  79.699    -  internal nodes usually
           APRIL  66.636       do not have temp. data
             MAY  55.717
            JUNE 102.629
            JULY  37.611
          AUGUST  20.458
            SEPT  16.186
```

```
1960-61      OCT  22.610
             NOV  26.632
             DEC  12.808
             JAN  13.112
             FEB  14.819
           MARCH  31.613
           APRIL  37.671
             MAY  33.112
                .
                .
                .
                .
```

3.3.5 HYDOUT -- The HYDROSS output file

HYDOUT is the source of the flow values from a simulated system operation using HYDROSS. It is an unformatted file that cannot be read at the terminal. The linkage program reads this file and checks that it contains the requested network information. The contents of the file can be printed by running the HYDROSS model report procedure (Waddle in prep.). This file also must not be viewed with XEDIT.

3.4 Description of Output Files

There are two primary output files: the revised SNTEMP hydrology data L1HUP and the job summary (MESSGS).

3.4.1 L1HUP - With the exception of the first two records, the revised hydrology data file is formatted identically to the original hydrology data file L1HYD. The first title line has the abbreviation UPDAT inserted in columns 76 - 80. The second line, which is normally blank, contains the linkage run title from L1JCF to show the source of the revised flow data.

Example output follows:

```
HYDROLOGY DATA SET FILE: UPPER COLORADO RIVER BASIN--VERIFICATION DATA UPDAT

LINKED FLOWS FOR:  TEST OF HYDROSS - TEMP. MODEL LINKAGE USING GREEN/YAMPA DEM

GREEN RIVER      S 1S2       661.3 FLAMING GORGE DAM
 1959-60      OCT  22.603
              NOV  20.842
              DEC  18.172
              JAN  17.327
              FEB  23.009
            MARCH  59.835     2.67
            APRIL  38.836     9.55
              MAY  32.134    12.50
             JUNE  73.208    17.55
             JULY  23.403    20.50
           AUGUST  14.228    19.00
             SEPT  19.610    16.64
 1960-61      OCT  16.605     8.17
              NOV  24.693     1.21
              DEC  19.021
              JAN  12.470     0.51
              FEB  13.840     1.04
                  .
                  .
                  .
                  .
             SEPT  51.930     9.83

GREEN RIVER      B           556.7 YAMPA RIVER CONFLUENCE
 1959-60      OCT  31.695
              NOV  25.774
              DEC  15.636
              JAN  13.063
              FEB  15.213
            MARCH  79.699
            APRIL  66.636
              MAY  55.717
             JUNE 102.629
             JULY  37.611
           AUGUST  20.458
             SEPT  16.186
 1960-61      OCT  22.610
              NOV  26.632
              DEC  12.808
              JAN  13.112
              FEB  14.819
            MARCH  31.613
            APRIL  37.671
              MAY  33.112
                  .
                  .
                  .
                  .
```

End of example

3.4.2 MESSGS - Job summary output file

MESSGS contains a complete description of how the job runs, the sequence of processing events, and warning and error messages. You should study this output file carefully because it will be an immense help in making sure that you have set up your data files correctly. It should also be invaluable as a record of what you did to accomplish a certain option, along with the date and time of the run. Running several scenarios (i.e., many precursor, postcursor, and linkage runs) tends to create a great deal of paper and chances for confusion. Use this file as a record of the options chosen in each run.

The following is an example of file MESSGS with some truncations for brevity. (Note that the file names are the names used for the actual run and not the generic names used in this documentation.)

```
 STREAM NETWORK FLOW MODEL ≡--> STREAM NETWORK
  TEMPERATURE MODEL LINKAGE  /   STUDY TITLE:
 TEST OF HYDROSS - TEMP. MODEL LINKAGE USING GREEN/YAMPA DEM
 AS OF DATE:  84/08/26. 15.38.27.
================================================================================
FILES USED IN PROCESSING FLOW ≡--³ TEMP LINKAGE:
           ZLNKCTL - LINKAGE CONTROL FILE
           MESSGS  - RUN STATUS AND ERROR MESSAGES
           ZTSTJOB - SNTEMP JOB CONTROL FILE
           ZTSTHDR - SNTEMP HYDROLOGY NODE FILE
           ZTSTHYD - SNTEMP HYDROLOGY DATA FILE
           L1HUP   - NEW HYDROLOGY DATA FILE
           HYDOUT - FLOW MODEL OUTPUT, HYDROLOGY SOURCE DATA

*** CHECKING TEMPERATURE MODEL JOB FILE ***

SNTEMP JOB CONTROL HEADING:
JOB CONTROL FILE: UPPER COLORADO RIVER BASIN--VERIFICATION DATA SET

*** END CHECKING OF TEMP. MODEL JOB FILE ***
==========

*** CHECKING TEMPERATURE MODEL HYDROLOGY NODE FILE LINKING RECORDS ***

SNTEMP NODE FILE HEADING:
HYDROLOGY NODE FILE: UPPER COLORADO RIVER BASIN--VERIFICATION DATA SET

HYDROLOGY NODES AND LINKING INFORMATION FROM TEMP. MODEL HYDROLOGY NODE FILE
NODE #    FILE ENTRY:

--------------------------------------------------------------------------------
 1 GREEN RIVER     S 1S2      661.3 FLAMING GORGE DAM
     234500 OUT                        GREEN RIVER FLAMING GORGE RES
--------------------------------------------------------------------------------
 2 GREEN RIVER     B 1        556.7 YAMPA RIVER CONFLUENCE
     240010 OUT                       GREEN RIVER ABOVE YAMPA CONFLUENCE
--------------------------------------------------------------------------------
                   .
                   . Syntax errors will appear here with
                   . the erroneous record.
                   .
--------------------------------------------------------------------------------
12 GREEN RIVER     E 1        399.0 DUCHESNE RIVER CONFLUENCE
     261099 OUT                       GREEN ABOVE DUCHESNE CONFLUENCE

*** END OF ERROR CHECKING IN HYDROLOGY NODE FILE ***
==========
*** CHECKING HYDROSS NETWORK FOR REQUESTED LINKING INFORMATION ***

TITLE LINE FROM HYDROSS SIMULATION OUTPUT FILE: HYDOUT
```

```
  UPPER GREEN RIVER FOR HABITAT ANALYSIS 05/30/84 DEMONSTRAT
 CREATED ON  8/15/84  1849

 *** WARNING ***

 THE FLOW MODEL HAS FEWER YEARS OF DATA THAN THE TEMPERATURE MODEL DATA SET
 MATCHING INFORMATION WILL ONLY BE GENERATED FOR YEAR   60
 THROUGH YEAR   78. REVISE THE TEMPERATURE MODEL JOB
 CONTROL FILE L1JOB BEFORE GAMING.

 THE HYDROSS NETWORK CONTAINS THE FOLLOWING CONTROL POINTS
------------------------------------------------------------------------------
 211200  GREEN RIVER NAT FLOW AT FONTENELLE
------------------------------------------------------------------------------
 216510  GREEN RIVER AT FONTENELLE RESERVOIR
------------------------------------------------------------------------------
 220010  GREEN RIVER DEMAND PT BLW FONTENELLE RES
------------------------------------------------------------------------------
                   .
                   .
                   .
 261099  GREEN ABOVE DUCHESNE CONFLUENCE

 *** END OF CHECKING HYDROSS NETWORK FOR REQUESTED  LINKING INFORMATION ***
 ==========

*** BEGIN EXTRACTION OF FLOW INFORMATION FROM STREAM
   NETWORK MODEL OUTPUT FILE ***

 HYDROSS FLOW DATA FROM FILE HYDOUT A/O DATE:AUG 15,1984 1849

 *** BEGIN UPDATE OF HYDROLOGY DATA FILE ***

 HYDROLOGY NODES PROCESSED FROM FILE L1HYD:

------------------------------------------------------------------------------
 GREEN RIVER     S 1S2      661.3 FLAMING GORGE DAM
------------------------------------------------------------------------------
 GREEN RIVER     B          556.7 YAMPA RIVER CONFLUENCE
------------------------------------------------------------------------------
                      .
                      .
                      .
                      .
------------------------------------------------------------------------------
 GREEN RIVER     E          399.0 DUCHESNE RIVER CONFLUENCE

 *** HYDROLOGY UPDATE COMPLETED ***
 ==================================================
 #  THERE WERE    0 FATAL ERRORS IN THIS LINKRUN   #
 #        AND     1 WARNING ERRORS                 #
 ==================================================
```

End of example.

3.5 Defaults

There are few defaults in LNKQ2T. Because of the sensitivity of simulated temperature results to proper linking of the models, many conditions have been trapped with fatal error messages. The program will default to the smallest number of common years of record and the smallest number of months per year that are common to the two models' hydrology data, and issue warning messages that these defaults have happened.

4.0 RELATED SOFTWARE

4.1 Precursors

There are two precursors to running LNKQ2T: SNTEMP and HYDROSS. Both are well beyond the scope of this documentation. However, there are a few hints to be passed along.

- HYDROSS - When organizing your HYDROSS data set you must remember to account for the required temperature nodes in the network description as noted earlier. We recommend that the final HYDROSS set-up be developed after SNTEMP has been run once.
- SNTEMP - Theurer et al. (1984) provide extensive guidance on organizing and implementing the temperature model. Please read that document before attempting a linked HYDROSS to SNTEMP study.

4.2 Alternative methods

There really are no alternatives at this point. Preparation of what-if hydrology data files is just too tedious to be done effectively by hand, which is why this linkage was developed. There is still an unanswered need for a reservoir temperature model to improve description of reservoir release temperatures.

4.3 Postcursors

Remember, if you alter the number of years in any of the SNTEMP data files to facilitate a linkage, you must change the temperature model job and meteorology data files to match the hydrology data file year span. Also, take a hard look at normals to be sure that they maintain consistency.

5.0 LIMITATIONS

5.1 Accuracy

LNKQ2T contains only one mathematical relationship to convert cubic meters per month from HYDROSS to cubic meters per second for SNTEMP. The conversion constants are accurate to at least four decimal places.

5.2 Known Deficiencies

LNKQ2T has been in use by Region 6 personnel for over 6 months. The bugs discovered as of 4/2/85 have been corrected and some features added to the program. It is possible that bugs will still be encountered. Please report them to IFG.

There is a minor error condition that arises should there be an improper syntax in the hydrology node file (L1HDR). This arises should you fail to have a 'J' node following a pair of 'B' and 'T' nodes in the SNTEMP hydrology node file, and produces a fatal error in SNTEMP. Running SNTEMP first will eliminate the likelihood of that condition occurring within this linkage because the error will have been found while running SNTEMP. Also, be sure to end with an 'E' node.

6.0 MESSAGES

Messages are divided into three categories: warning, fatal, and informative. These are listed separately, approximately in the order in which they might be encountered. In general, warning messages will not cause program termination. The job will do its best to continue. Fatal errors, however, will cause either immediate or delayed job termination, depending on the circumstances. The output file (OUTPUT) will provide a run summary total for these messages.

6.1 Warning Messages

1. *** WARNING *** THE NUMBER OF NODES SPECIFIED IN THE TEMPERATURE MODEL JOB FILE: ____ DOES NOT MATCH THE NUMBER PERFORMED WITH ____ NODES. YOU MUST CORRECT TEMP. MODEL JOB CONTROL AND ASSOCIATED FILES BEFORE GAMING

   Your networks do not match. Either alter the SNTEMP network to match that derived from this linkage or reorganize the HYDROSS network (and rerun HYDROSS) so it can provide the needed information for SNTEMP.

2. *** WARNING *** THE RIVER NETWORK MODEL STARTING YEAR ____ IS LATER THAN THE TEMPERATURE MODEL STARTING YEAR ____ LINKED FLOW INFORMATION WILL ONLY BE GENERATED FROM YEAR ____ REVISE THE SNTEMP JOB CONTROL FILE _______ BEFORE GAMING

   In many cases one or the other of the models may have been run for a different period of years than is common to them. As long as this matching period of years is sufficient for the study at hand, you need to revise all temperature model files to correspond to this matched period or rerun HYDROSS to cover the necessary years for the temperature model. This is a warning message because the linkage will run. However, SNTEMP may fail.

3. *** WARNING *** THE FLOW MODEL HAS FEWER YEARS OF DATA THAN THE TEMPERATURE MODEL DATA SET. MATCHING INFORMATION WILL ONLY BE GENERATED FOR YEAR ____ THROUGH YEAR ____ . REVISE THE TEMPERATURE MODEL JOB CONTROL FILE ________ BEFORE GAMING

   See warning message description No. 2.

d. *** WARNING *** A RESERVOIR WAS EXPECTED AT CONTROL POINT _____ IN HYDROSS BUT NOT FOUND. THIS LOCATION WILL BE TREATED AS A NO-STORAGE RESERVOIR. HOWEVER, YOU SHOULD REVIEW THE HYDROSS NETWORK AND SNTEMP HYDROLOGY NODE FILES.

   You have asked for a reservoir at station ________, but there was no reservoir located there in the HYDROSS run that produced file HYDOUT. It is possible that you have a HYDOUT from the wrong HYDROSS case or that there is no structure at that location. Check the HYDROSS and SNTEMP networks for compatibility. Re-run HYDROSS or SNTEMP if necessary for the analysis being performed.

6.2 Fatal Messages

1. FATAL ERROR 1: FILE _______ DOES NOT CONFORM TO HYDROLOGY DATA FORMAT IT MAY BE THE WRONG FILE. FIRST 10 LINES PRINTED FOR REFERENCE.

   The wrong file was specified as the hydrology data file L1HDR. Re-run with correct hydrology data file.

2. FATAL ERROR 2: END FOUND ON _____ CHECK FILE LENGTH AND CONTENTS. EITHER THE WRONG FILE WAS SPECIFIED AS THE HYDROLOGY DATA FILE OR NO FILE WAS SPECIFIED. CORRECT AND RE-RUN.

   Check your L1HDR file. Is it local? Was it typed correctly? Then re-run.

3. FATAL ERROR 3: LINKRUN WAS DIRECTED TO PRODUCE NORMALS (NORM2.GT.0) BUT NORM1=0 INDICATES NORMALS ARE NOT AVAILABLE FROM SNTEMP

   The normal flags in the L1JCL file are set inconsistently. This linkage is only able to replace normals in the file L1HUP, so if SNTEMP was not run with normals, the linkage cannot produce them. Revise L1JCL accordingly.

4. FATAL ERROR 4: UNEXPECTED END FOUND ON LINKAGE CONTROL FILE: ______________________________ CHECK FILE FOR COMPLETENESS AND/OR CORRECT NAME

   You may have provided the wrong file name in your study-specific procedure, or your L1JCL file is incomplete. Check for both problems, correct and re-run.

5. FATAL ERROR 5: THE NUMBER OF TEMP. MODEL TIME STEPS PER YEAR ____ IS GREATER THAN 12

   Though the temperature model can be run on more than 12 time steps per year, HYDROSS is strictly a monthly model. This linkage is only able to link to SNTEMP runs that have been set up on a monthly basis.

6. FATAL ERROR 6: A HEADWATER NODE WAS MISMATCHED. EXPECTED "IN" OR "OUT" BUT FOUND " ______ "

   All errors that give a "mismatched" message refer to how the L1HDR linkage file was set up. By looking at the matching record printed above the error, you will see what was found instead of the expected quantities stated. This should allow you to determine if you merely had data in the wrong columns or if needed records are missing.

7. FATAL ERROR 7: A DIVERSION NODE WAS MISMATCHED. EXPECTED "DIV" BUT FOUND " ______ "

   See fatal message description No. 6.

8. FATAL ERROR 8: DIVERSION NUMBER MISSING

   Diversions also require the diversion number to avoid confusion among diversions; revise L1HDR and re-run.

9. FATAL ERROR 9: A RETURN FLOW NODE WAS MISMATCHED. EXPECTED "RF" BUT FOUND "___"

   See fatal message description No. 6.

10. FATAL ERROR 10: RETURN FLOW TYPE MISSING

    Return flows require the type to be specified, because more than one type of return flow can accrue from a diversion in HYDROSS; revise L1HDR and re-run.

11. FATAL ERROR 11: RETURN FLOW REQUIRES A SOURCE DIVERSION

    A return flow cannot be uniquely identified unless the originating diversion is known. Revise L1HDR to include the diversion that is the source of this return flow and re-run.

12. FATAL ERROR 12: A STRUCTURE NODE WAS MISMATCHED. EXPECTED "IN" OR "OUT" BUT FOUND "___"

    See fatal message description No. 6.

13. FATAL ERROR 13: AN INTERNAL STRUCTURE NODE REQUIRES BOTH INFLOW AND OUTFLOW LINKAGE "IN" WAS FOUND BUT "____" WAS FOUND INSTEAD OF "OUT"

    You must instruct the linkage to look for both inflow and outflow at an internal structure node. Revise L1HDR and re-run.

14. FATAL ERROR 14: A BRANCH NODE WAS MISMATCHED. EXPECTED "OUT" BUT FOUND "____"

    See fatal message description No. 6.

15. FATAL ERROR 15 : A TERMINUS NODE WAS MISMATCHED. EXPECTED "OUT" BUT FOUND "____"

    See fatal message description No. 6.

16. FATAL ERROR 16: THE END NODE WAS MISMATCHED. EXPECTED "OUT" BUT FOUND "____"

    See fatal message description No. 6.

17. FATAL ERROR 17: A FLOW(Q) NODE WAS MISMATCHED. EXPECTED "IN" OR "OUT" BUT FOUND "____"

    See fatal message description No. 6.

18. FATAL ERROR 18: A POINT SOURCE NODE WAS MISMATCHED. EXPECTED "RF" OR "OTH" BUT FOUND "____"

    See fatal message description No. 6.

19. FATAL ERROR 19: A VERIFICATION NODE WAS MISMATCHED. EXPECTED "IN" OR "OUT" BUT FOUND "____"

    See fatal message description No. 6.

20. FATAL ERROR 20: A CALIBRATION NODE WAS MISMATCHED. EXPECTED "IN" OR "OUT" BUT FOUND "____"

    See fatal message description No. 6.

21. FATAL ERROR 21: THE NUMBER OF HYDROLOGY NODES: _____ EXCEEDS THE ALLOWED MAXIMUM (200)

    The linkage program has been dimensioned to handle 200 SNTEMP hydrology nodes. For large programs, the dimensions will need to be increased and the program re-compiled. Contact the Instream Flow Group.

22. FATAL ERROR 22: UNEXPECTED END FOUND ON TEMP. MODEL CONTROL FILE CHECK IF FILE EXISTS AND IS LOCAL THEN RERUN LINKAGE

    You may not have supplied the proper name for L1JOB or you do not have an SNTEMP job control file, but have some other file specified by mistake. Check the file and revise your study-specific procedure accordingly.

23. FATAL ERROR 23: UNEXPECTED END FOUND ON TEMP. MODEL HYDROLOGY NODE FILE CHECK IF FILE EXISTS AND IS LOCAL THEN RERUN LINKAGE

    You may have supplied a L1HDR file from another study that does not match the L1JOB file or a file that is not a L1HDR type file at all. Check both the L1JOB and L1HDR files to be sure you have the right files identified for this study. Correct either the study procedure or the files and re-run.

24. FATAL ERROR 24: UNEXPECTED END FOUND ON TEMP. MODEL HYDROLOGY NODE FILE CHECK FILE LENGTH AND NUMBER OF NODES IN IT AND IN TEMPERATURE MODEL JOB FILE FOR MIS-MATCH

    See fatal message description No. 23.

25. FATAL ERROR 25: NO LINKING INFORMATION FOUND IN TEMPERATURE MODEL HYDROLOGY NODE FILE. SO NO LINKAGE PERFORMED. ADD MATCHING RECORDS TO NODE FILE AND RERUN LINKAGE.

    You forgot to add linking records to the SNTEMP hydrology node file L1HDR. Revise that file and re-run.

26. FATAL ERROR 26: THE LAST YEAR OF HYDROSS DATA: 19__ IS EARLIER THAN THE FIRST YEAR OF TEMPERATURE DATA: 19__ CHECK YOUR FILES

    There is no overlapping time period so the linkage cannot run. Check that you have the right files specified. You may have picked files from the wrong studies. Revise study procedure and re-run.

27. FATAL ERROR 27: MATCHING CONTROL PT ____________________ HAS NO EQUIVALENT IN THE HYDROSS NETWORK REVIEW THE HYDROSS NETWORK AND SNTEMP HYDROLOGY NODE FILES

    You have asked the linkage to find a HYDROSS station that does not exist in the HYDROSS data file HYDOUT. Run the HYDROSS report program to find the stations in HYDOUT. If there is a station that will provide the necessary linkage information, revise the L1HDR file and re-run.

28. FATAL ERROR 28: A DIVERSION WAS EXPECTED AT CONTROL POINT __________ IN HYDROSS BUT NOT FOUND REVIEW THE HYDROSS NETWORK AND TEMP. MODEL HYDROLOGY NODE FILES

You have asked for a diversion at station ________ but there was no diversion located there in the HYDROSS run that produced file HYDOUT. It is possible that you have a HYDOUT from the wrong HYDROSS case or that there is no structure at that location. Check the HYDROSS and SNTEMP networks for compatibility; re-run HYDROSS or SNTEMP, if necessary, for the analysis being performed.

29. FATAL ERROR 29: NO RETURN FLOW WAS FOUND IN THE HYDROSS NETWORK THAT MATCHES THIS REQUESTED RF: ____ FLOINIT

    See fatal message description No. 28.

30. FATAL ERROR 30: HYDROSS NETWORK SIZE EXCEEDS CAPACITY OF LINKAGE PROGRAM PARAMETER VALUES:

STA	DIV	RES	PWR	INFLO	CRES	RF	
____	____	____	____	____	____	____	MAXIMUM
____	____	____	____	____	____	____	NETWORK

    This is a second check to ensure the linkage program can handle your study. If this message is issued, call the Instream Flow Group for program assistance.

31. FATAL ERROR 31: UNEXPECTED END FOUND ON HYDROSS FILE WHILE PROCESSING RETURN FLOWS. THIS SHOULD NOT HAPPEN. GET HELP.

    Call the Instream Flow Group,quick.

32. FATAL ERROR 32: AN ERROR OCCURRED WHILE WRITING TO IOSCR. THIS SHOULD NOT HAPPEN. ERR NR WAS ____ GET HELP.

    Call the Instream Flow Group.

33. FATAL ERROR 33: END OF FILE FOUND ON _______ WHILE READING HEADINGS CHECK FILE AND RE-RUN

    Either the wrong file or no file was entered as the hydrology data file L1HYD.

34. FATAL ERROR 34: END OF FILE FOUND ON _______ WHILE SEARCHING FOR COMMON STARTING YEAR. LAST YEAR READ WAS ____ ON STATION ______.

    The hydrology data file L1HYD did not have as many years of data as were indicated in the SNTEMP job control file L1JOB. You may have mismatched files from different studies or different cases within your current study. Check those files and revise the study procedure file accordingly.

35. FATAL ERROR 35: TEMP. MODEL HYDROLOGY FILE ONLY GOES THROUGH _______ EXPECTED ____________

    See fatal message description No. 34.

36. FATAL ERROR 36: END OF FILE FOUND ON ______ WHILE PROCESSING FLOW DATA LAST YEAR READ WAS ____ ON STATION ________ CHECK FILE CONTENTS AND LENGTH

See fatal message description No. 34.

37. FATAL ERROR 37: FLOW DATA ON STATION ______. CHECK FILE CONTENTS AND LENGTH

See fatal message description No. 34.

6.3 Informative Messages

The following message is issued at the end of file MESSGS to remind you of the number of problems that occurred during the linkage run. If there were warning errors but no fatal errors, be sure to check the conditions of the warning messages before proceeding.

```
==================================================
#                                                #
#  THERE WERE ___ FATAL ERRORS IN THIS LINKRUN   #
#        AND  ___ WARNING ERRORS                 #
#                                                #
==================================================
```

The next messages are issued to the terminal (or output file in a batch job) and tell you what kinds of errors to look for on file MESSGS. Only one of these messages will occur at the end of a run.

```
$$$$ WARNING ERRORS ENCOUNTERED $$$$
SEE FILE MESSGS BEFORE PROCEEDING

$$$$$ LINKAGE ABORTED $$$$$
SEE FILE MESSGS FOR DETAILS

$$$$$ NO ERRORS ENCOUNTERED $$$$$
RUN SUMMARY ON FILE MESSGS
```

End of informative messages.

7.0 TIME AND COST

A typical run for a small 14-node SNTEMP network with 12 years of data would take about 10 seconds and cost about $8.00 in normal daytime 1200 baud service. Costs are reduced substantially in batch mode to about $4.00, but may be expected to take up to 5 minutes, depending on the system load. Users are encouraged to use batch jobs for large networks to reduce costs.

8.0 UNUSUAL APPLICATIONS -- none.

9.0 POSSIBLE MODIFICATIONS

The HYDROSS model is currently being revised by the Bureau of Reclamation in Billings, MT. This linkage will need to be revised when their new version is available. Possible revisions include changing the unit conversions to accommodate English unit output from HYDROSS and revised tracking of diversions and return flows.

10.0 SUPPLEMENTAL MATERIAL & REFERENCES

Theurer, Fred J., Kenneth A. Voos and William J. Miller. 1984. Instream Water Temperature Model. Cooperative Instream Flow Service Group, Instream Flow Information Paper No. 16. FWS/OBS-84/15. 335 pp.

Waddle, Terry J. HYDROSS User Notes. In preparation.

Also refer to documentation for LNKQ2T and other linkage programs in this family.

11.0 HARDWARE

This program has been developed to run on Control Data Cooperation "Cyber" mainframes. The program uses the precursor program HYDROSS, which is entirely dependent on the Cyber mainframe environment. It may not pay to transfer this linkage to other machines with a re-write of HYDROSS.

12.0 ACKNOWLEDGMENTS

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APPENDIX B

TITLE -- LNKQ2H (Flow Model to Habitat Model) Version 1.1

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June 1984

1.0 INTRODUCTION

This program provides a linkage between a monthly reservoir and river network operations planning model, HYDROSS (U.S. Bureau of Reclamation, Upper Missouri Region), and the Physical Habitat Simulation Model, PHABSIM, developed by the Cooperative Instream Flow Service Group, U.S. Fish and Wildlife Service.

This linkage will match the flows generated by HYDROSS with the habitat vs. flow relationship data from PHABSIM for one or more life stages at one or more locations to produce a networkwide habitat time series for each life stage.

The basic linkage between the stream network flow model and the stream habitat model is reasonably simple. This linkage is modeled after the existing program that link the flow model to the temperature model and is a member of a family of programs in the network habitat analysis family. This group consists of:

LNKQ2T - HYDROSS to TEMPERATURE MODEL
LNKT2H - TEMPERATURE to HABITAT MODEL
LNKQ2H - HYDROSS to HABITAT MODEL (this program)
LNKG2H - GAGE DATA to HABITAT MODEL
LNKT2TS - TEMPERATURE to TIME SERIES PROGRAM

For consistency, this documentation will refer to HYDROSS control points as stations, the temperature model control points as nodes, and the PHABSIM control points as sites.

The general outline of the program allows most monthly river system planning models or monthly time increment hydrology models to be linked to the PHABSIM model. Each linkage will require rewriting some routines to accommodate the individual stream network model's particular output characteristics.

2.0 EXECUTION

2.1 General Form

```
.PROC,GETQ2H.  GET FILES FOR LNKQ2H
GET,LNKQ2H.  GET THE PROGRAM
ATTACH,L2HYOUT=DEMOUT1.  GET HYDROSS OUTPUT (DIRECT ACCESS)
GET,L2HDR=hydrology node file.
GET,L2JCF=job control file.
GET,L2QA=flow vs habitat file.
REVERT.  OK
```

2.2 Conventions

Usually it is best to get your files by using a CDC procedure file. Then XEDIT your job control file (L2JCF) to achieve the desired outcome.

2.3 Batch Processing

```
/JOB.
JOHNB.
/USER.
/CHARGE.
PURGE,QOUT,QMES,QHTS/NA.
DEFINE,QOUT,QMES,QHTS.
BEGIN,GETQ2H,QJBP.
QLNKQ2H.
REWIND,OUTPUT,MESSGS,L2T10.
COPYEI,OUTPUT,QOUT.
COPYEI,MESSGS,QMES.
COPYEI,L2T10,QHTS.
DAYFILE,QA.
REPLACE,QA.
EXIT.
REWIND,OUTPUT,MESSGS.
COPYEI,OUTPUT,QOUT.
COPYEI,MESSGS,QMES.
DAYFILE,QAA.
REPLACE,QAA.
```

3.0 APPLICATION

3.1 Description of Logic

From a user's perspective, LNKQ2H does these things:

Opens and rewinds all files necessary for operation (Figure 1):

Input:

- L2HYOUT - HYDROSS output file, must be local.
- L2QA - Habitat vs. Flow data file, must be local.
- L2HDR - Hydrology node linking file, must be local.
- L2JCF - Job control file, must be local.

Output:

- OUTPUT - For brief program termination messages.
- MESSGS - For run status, error messages and summary report. This file is rewound at the end of the run.
- L2T10 - For the habitat time series data. This file is rewound at the end of the run.
- Reads the hydrology node data file to determine which HYDROSS stations are needed. The data file is checked for proper syntax.
- Reads HYDROSS output to get linking flows.
- Reads the Habitat vs. Flow data file and links its data to the proper hydrology nodes.
- Reads the job control data file for the desired time span, nodes, life stages, etc.
- Creates the appropriate habitat time series file by converting the HYDROSS flows to their corresponding habitat values. Habitat values are aggregated over space for each life stage.
- Writes a summary report for each life stage that covers the minimum, average, and maximum values recorded for each life stage.

3.2 Options

The primary options for this program are controlled by the job control data file (L2JCF). Through the proper use of this file, you may control which nodes to aggregate, which life stages to be used, and what time period, both in years and months, is to be covered. In this way, comparisons may easily be made across both time and space for any biological requirement.

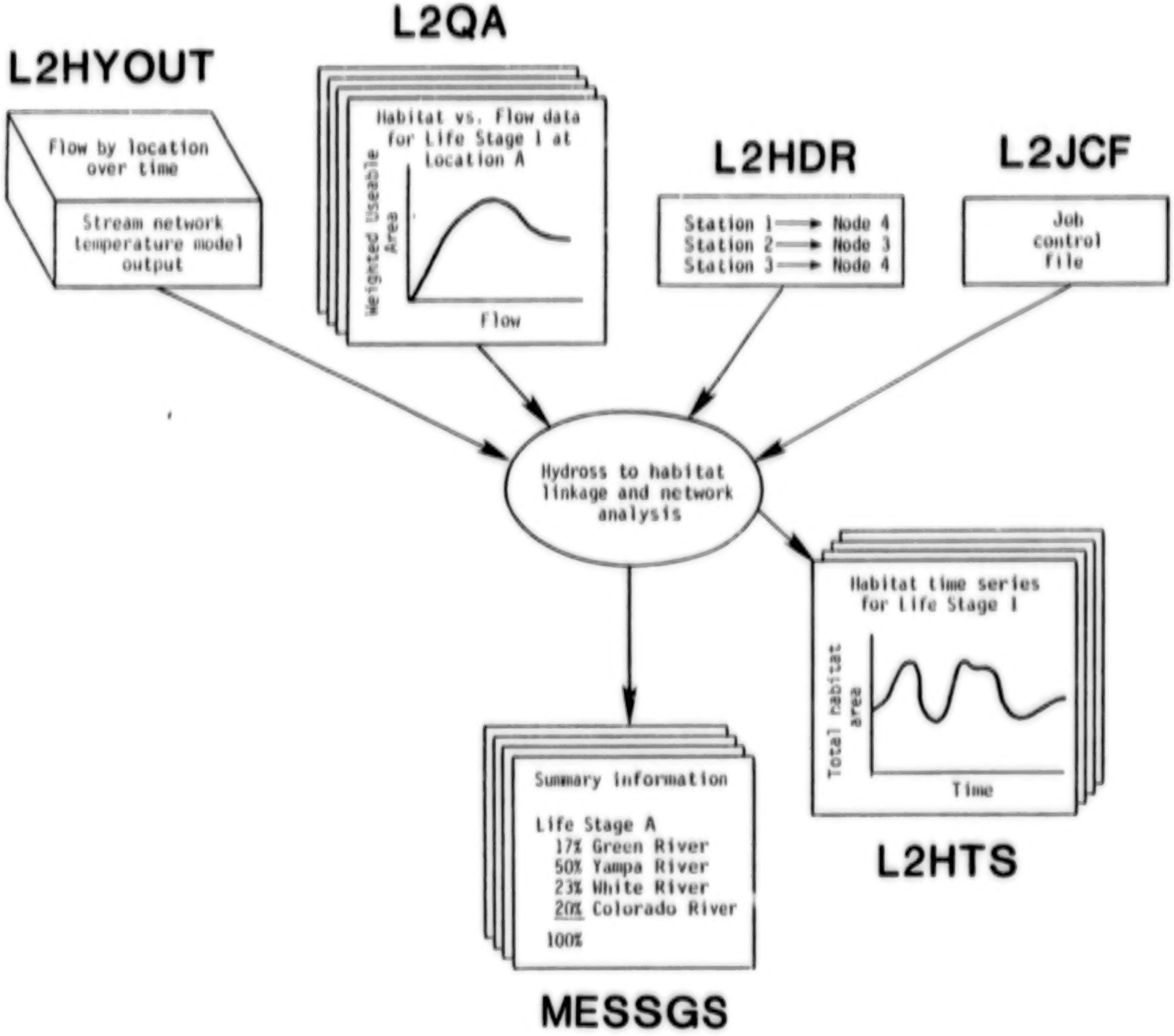


Figure 1. Essential input and output files for flow model to habitat model linkage.

Other options are effectively provided with the other data input files. For example, weights may be applied to each life stage at each node representing the river reach length and/or relative priority to be assigned to the habitat value at that location. Of less importance, perhaps, is the ability to control which HYDROSS flows are to be aggregated to form the flow for any specific geographic location.

3.3 Input Files Description

3.3.1 L2HDR - Hydrology Node File, formatted

The file L2HDR contains the hydrology network information for the PHABSIM model and the linking information to the river network model. This linkage requires that the hydrology node file have records inserted to indicate which HYDROSS model information is to be matched to which PHABSIM model site. Up to nine matching records are read from the hydrology node file. Each record contains the flow model station number, four fields of matching information (some of which may not be used), and up to 56 columns of descriptive information for that node with pointers to HYDROSS stations.

Note that proper use of the hydrology node file will enable you to link more than one site to a single HYDROSS station or group of stations. That is, any node link may refer to any HYDROSS station. In this way, more than one habitat site in a reach which has the same flow may refer to a single stations's flow. However, there may not be more than one individual life stage represented at any one site. See the description of the L2QA data file.

General description of hydrology node file:

- Title line columns 1-80.
- Record 2 and every other hydrology node record:

Columns	Description
1 -16	Stream name
17-24	Node type identifier
25-32	Distance (km) from the system end point
33-80	Remarks to describe node

- Each linking record contains flow network model station information that corresponds to the habitat hydrology node.
- When more than one station record from the flow model is associated with a hydrology node it is assumed that those flow values are summed. That is, if three return flows arrive at a single point, their effect is summed before

passing to habitat node file. If they arrive at three separate points they should be represented in the habitat site file as three additional nodes if there are points of biological interest intervening. If there are no intervening points of biological interest, they do not need to be represented as three additional nodes.

- For interfacing to HYDROSS the linking record format is:

Column	Format	Contents
1-2	blank	
3-8	a6	6 digit station identification
9	blank	
10-12	a3	linking information type to be extracted from HYDROSS station as follows: station inflow - IN station outflow - OUT diversion from station - DIV return flow to station - RF
13-15		diversion number, i.e., 005 for D005 or return flow type as " 4" , " 2", etc. Please refer to HYDROSS users' manual for details
16	blank	
17-19	a4	additional linking information as needed DIV - diversion for a return flow's source OUT - station outflow for structures blank for all others
20-22		diversion number reference for a return flow node

A summary of the syntax checks performed on this data file is as follows:

--- at an 'H' headwater, test for IN or OUT
--- at a 'D' diversion, test for DIV and div #
--- at a 'R' return flow, test for RF and rf type then DIV and div #
--- at a 'S' structure, test for OUT
--- at a 'B' branch, test for OUT
--- at a 'T' terminus, test for OUT
--- at the 'E' end node, test for OUT
--- at a 'Q' node, test for IN or OUT
--- at a 'P' point source node, test for RF or OTH
--- at a 'C' calibration node, test for IN or OUT

If these checks are not met, warning messages are printed. Many of these errors would be fatal.

An example hydrology node file is shown in Figure 2.

```
HYDROSS - PHABSIM MODEL HYDROLOGY NODE FILE FOR LINK TEST
YAMPA RIVER     H 1        697.5 HEADWATER ABOVE MAYBELL
  250010 OUT                     KNOWN GAGE ABOVE MAYBELL
YAMPA RIVER     D 1        697.0 DIVERSION FOR ALL USES ABOVE LITTLE SNAKE
  250010 DIV250                  HYDROSS DIVERSION
YAMPA RIVER     R 1        690.1 ABOVE JUNIPER SPRINGS DAM SITE
  251000 RF    2 DIV250          RETURN POINT FOR ALL UPPER YAMPA DIVERSIONS
YAMPA RIVER     Q 1        681.5 MAYBELL
  251000 OUT                     LINK TO MAYBELL HAB SITE
YAMPA RIVER     Q 1        652.0 CROSS MOUNTAIN
  252000 OUT                     LINK TO CROSS MTN. HABITAT SITE
YAMPA RIVER     B 1        638.8 LITTLE SNAKE CONFLUENCE
  259010 OUT                     LINK TO LILY PARK HABITAT SITE
LITTLE SNAKE    H 1        651.6 LILY GAGE
  259700 OUT                     LINK TO 'NATURAL' FLOW
LITTLE SNAKE    D 1        651.5 DIVERSION BELOW LILY GAGE
  259700 DIV251                  COLORADO AG. USES ON LITTLE SNAKE
LITTLE SNAKE    R 1        651.4 WYOMING DEMAND POINT
  259810 RF    2 DIV251          COLORADO AG. USES ON LITTLE SNAKE
LITTLE SNAKE    D 1        651.3 WYOMING DEMAND POINT
  259810 DIV252                  WYOMING AG,M&I AND EXPORT ON LITTLE SNAKE
LITTLE SNAKE    R 1        651.2 MOUTH AT YAMPA CONFLUENCE
  260000 RF    2 DIV252          WYOMING AG., M&I AND EXPORT ON LITTLE SNAKE
LITTLE SNAKE    T 1        638.8 MOUTH AT YAMPA CONFLUENCE
  260000 OUT                     LINK TO MANTLE,CLEOPATRA & BOX ELDER HAB SITES
YAMPA RIVER     J          638.8 BELOW LITTLE SNAKE CONFLUENCE
YAMPA RIVER     C 1        627.5 LILY PARK
  260099 OUT                     LINK TO MANTLE RANCH HABITAT SITE
YAMPA RIVER     C 1        585.7 HARDING HOLE
  260099 OUT                     LINK TO CLEOPATRA'S COUCH HABITAT SITE
YAMPA RIVER     B 1        556.7 GREEN RIVER CONFLUENCE
  260099 OUT                     LINK TO BOX ELDER HABITAT SITE
GREEN RIVER     O 1        423.2 OURAY REFUGE STUDY SITE
  261050 OUT                     LINK TO OURAY HABITAT SITE
```

Figure 2. Example hydrology node file (L2HDR).

3.3.2 L2QA - Habitat vs. Flow Data file, formatted

This file contains one species/life stage per record with records separated by at least 10 asterisks (**********).

For each record:

Line 1 is a title line. This line may need to be deleted for some other PHABSIM applications such as PLTTP8.

Line 2 will be the site identifier. This will correspond to a hydrology node in format. In fact, it will have to match exactly nodes read from the hydrology node file.

Lines 3 & 4 will be title lines, skipped for this program, but handy to keep track of your data. Again, other PHABSIM applications may require that these titles be deleted.

Line 5 is the species line:

Column	Format	Description
1-10	A	Species Name
11-29	blank	
31-41	A	12 monthly flags, 1 if month applicable, 0 if not. These values are necessary at all nodes; month one is January for this program (OR as HYDROSS dictates).
45-54	F10.0	Habitat threshold -- If the population's usable area falls below this value (in thousands of square feet) in any month, a warning error will be printed.
55-64	F10.0	Downstream distance, measured in miles, is the multiplier for the WUA. The downstream distance is the reach length for which one assumes that the PHABSIM hydraulics and preference criteria apply. Note that if one scenario calls for a reservoir that will inundate part or all of a 'biological' reach, you must account for that inundation by adjusting the distance factor. Also, this distance may be adjusted to account for a life stage 'weight'.

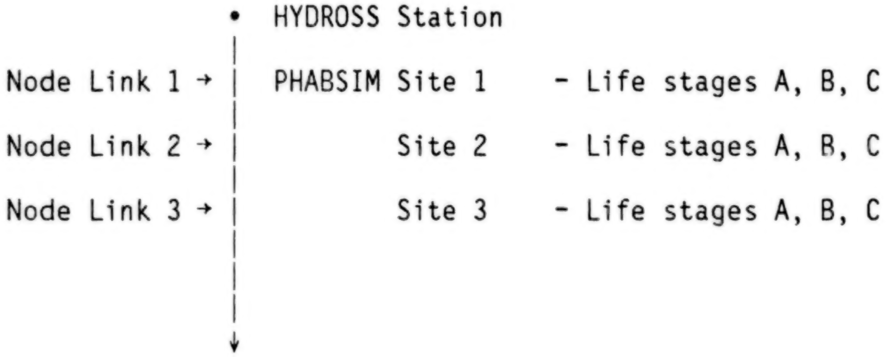
Line 6 is 'DISCHARGE' and life stage data line:

Column	Format	Description
18-27	A	Life Stage Name

Line 7 thru N is the Q and WUA data (3X,2F12.0) followed by Line N+1 which is **********, End Of Logical Record. There may be a true -EOR- in the file at this point. This is optional.

Then the format repeats for each new node/life stage. The time, threshold, and distance are required for each node/life stage because they may differ throughout the network. That is, a life stage at one point may have different time and threshold values than at another point.

Note that there may not be more than one identical life stage referring to a single node. For example, suppose that there are three habitat sites in a single stretch of river.



If life stages A, B, and C were found at each habitat site, their respective curves must each refer to different nodes in the hydrology node file (L2HDR). In this case, one would need to create new or dummy nodes. Each of these dummy nodes may refer to the same HYDROSS station. See the discussion under the hydrology node file.

An example flow - WUA data file is shown in Figure 3.

3.3.3 L2JCF -- Job Control File, formatted

The job control file may be used to control the overall execution of this program. An example of the job control file is shown in Figure 4. This file should be fairly straightforward.

The title that ends up on the habitat time series file (L2T10) is the first title line in the job control file.

Both the nodes list and life stage list correspond to the order in which the nodes appear in the hydrology node file (L2HDR) and the habitat vs. flow data file (L2QA). If in doubt, refer to the MESSGS listing where the node numbers and life stage numbers will be printed. NOTE that if you remove nodes or life stages from these data files, you may need to adjust the job control file accordingly.

```
FLOW/HABITAT VALUE FILE FOR UPPER COLORADO TEST ASSEMBLED BY BARTHOLOW MAY 84
YAMPA RIVER      Q 1        681.5 MAYBELL
DATA FROM PREWITT - JAN 1982 COMPLETION REPORT  YAMPA-WHITE PHYSICAL HABITAT INTERPRETED FROM GRAPH ON P.12
EXTRA TITLE LINE
SQUAWFISH                     111100001111         0.00      13.00
      DISCHARGE  ADULT
           0.0         0.0      ADDED BY BARTHOLOW
         200.00      1000.00
         500.00      2000.00
        1700.00      1000.00
       10000.00       500.00
       20000.00         0.00     ADDED BY BARTHOLOW
***************
YAMPA RIVER      Q 1        681.5 MAYBELL
DATA FROM PREWITT - JAN 1982 COMPLETION REPORT  YAMPA-WHITE PHYSICAL HABITAT INTERPRETED FROM GRAPH ON P.12
EXTRA TITLE LINE
SQUAWFISH                     000001111000         0.00      13.00
      DISCHARGE  YOY
           0.0         0.0      ADDED BY BARTHOLOW
         200.00      1000.00
         500.00       500.00
       10000.00       100.00
       20000.00         0.00     ADDED BY BARTHOLOW
***************
YAMPA RIVER      C 1        585.7 HARDING HOLE
DATA FROM PREWITT - JAN 1982 COMPLETION REPORT  YAMPA-WHITE PHYSICAL HABITAT INTERPRETED FROM GRAPH ON P.18
EXTRA TITLE LINE
SQUAWFISH                     000001110000         0.00       0.19
      DISCHARGE  SPAWNING
           0.00        0.00     ADDED BY BARTHOLOW
         250.00     7500.00
         400.00    13000.00
         600.00    19000.00
         800.00    24000.00
        1000.00    27000.00
        1200.00    31000.00
       22500.00        0.00     INTERPOLATED BY BARTHOLOW
```

Figure 3. Example flow - WUA file (L2QA).

```
***************
GREEN RIVER      0 1        423.2 OURAY REFUGE STUDY SITE
1-20000 CFS.
DATA RUN BY BRUCE WAHLE -- MAY 1984
EXTRA TITLE LINE
SQUAWFISH                  111100001111          0.00      15.00
      DISCHARGE  ADULT
           1.00    43537.08
          25.00    39873.88
          50.00    44123.34
          75.00    44867.19
         100.00    44918.49
         200.00    44347.63
         300.00    43695.20
         400.00    41141.96
         500.00    39372.34
         600.00    38620.37
         700.00    37767.79
         800.00    37023.06
         900.00    36120.11
        1000.00    35907.06
        2000.00    39692.00
        3000.00    42165.00
        4000.00    44068.85
        5000.00    43754.18
        6000.00    41901.08
        7000.00    39663.41
        8000.00    39023.05
        9000.00    37158.67
       10000.00    35026.61
       11000.00    32402.88
       13000.00    30622.23
       15000.00    28340.38
       20000.00    15572.38
       24724.00        0.00     DATA INTERPOLATED BY WAHLE
```

Figure 3. (Concluded)

```
HYDROSS TO MICRO-HABITAT LINK; FULL TEST OF CAPABILITY (80 CHARS FREE FORMAT)
CY: SQFT    WILL DEFINE TOTAL AREA IN NETWORK           (A10,A)
FIRST YEAR             65                               (20X,I5)
LAST YEAR              78                               (20X,I5)
MONTHS              111111111111 1 to include, else 0   (20X,A)
NUMBER OF NODES         7                               (20X,I5)
NODES LIST              4    5    6   14   15   16   17 (20X,10I5)
NUMBER OF LIFES         7                               (20X,I5)
LIFE STAGE LIST         1    2    3    4    5    6    7 (20X,10I5)
TAPE10 DATA FMT         0     0 FOR USGS; 1 FOR NWDC    (20X,I5)
```

Figure 4. Example Job Control File (L2JCF).

Notice that the first 10 characters of line 2 contain the units information that will be in the habitat time series output. LNKQ2H assumes that the flow data file from HYDROSS is in cubic meters per month. If this should change for any reason, the program would need to be modified. In fact, it should be modified at some point to recognize the units and account for them in a general sense. The year type (calendar or water) makes no difference to LNKQ2H, though the current form of the HYDROSS output file is in calendar year format. To get in the habit of using proper units, please follow the format given below. If you do not, a warning message will be printed.

Time codes which are in cols 1 - 3 (with a trailing :):
1 AY: = agricultural year
2 CY: = calendar year
3 WY: = water year
4 IY: = irregular year
5 = blank

Scale factors which may be in column 4:
1 none = 1.0
2 K = 1 x 10^3
3 M = 1 x 10^6
4 G = 1 x 10^9

Measurement units codes in cols 5-10:
1 ACRES = acres
2 AF = acre feet
3 CFS = cubic feet per second
4 CMS = cubic meters per second
5 DAM3 = cubic decimeters
6 GPD = gallons per day
7 HECTS = hectares
8 IRREG = irregular
9 LPD = liters per day
10 SQFT = square feet
11 SQFT/K = square feet per 1000 feet
12 SQM = square meters
13 SQM/K = square meters per 1000 meters
14 WH = watt hours
15 $ = dollars
16 = blank
17 FT = feet
18 M = meters
19 MI = miles

3.4 Output Files Description

There are two primary output files: the habitat time series file (L2HTS) and the job summary (MESSGS).

3.4.1 L2T10 - Time series file is arranged one life stage per record. It may be convenient to pull off one record at a time from this file by using the procedure RGET1 from the PHABSIM PROCFIL or any other source. Example output is shown in Figure 5

Unlike a 'standard' USGS or NWDC time series file, this file's station descriptor says SUM. The reason for this is that the habitat values have been aggregated over a network and no single station identifier is relevant. The title of the habitat time series file comes directly from the job control file (L2JCF). The units also come from the first 10 characters of the job file's second title line, except that they have been divided by 1000--thus the insertion of "K".

The very small numbers, 1.E-99, represent months in which the life stage has no biological habitat value. It is not zero, because zero might look like a realistic value. It was felt that a negative value might bomb out some programs and we know that zeros will bomb out some programs.

3.4.2 MESSGS - Job summary output file

MESSGS contains a complete description of how the job runs, the sequence of events, warning and error messages, and the summary report containing life stage statistics. You should study this output file carefully because it will be an immense help in making sure that you have set up your data files correctly. It will also be invaluable as a record of what you did to accomplish a certain option, along with the date and time of the run. An example of MESSGS is presented in Figure 6.

Past the run summary, the REPORT section should be of particular significance. This section lists for each species/life stage:

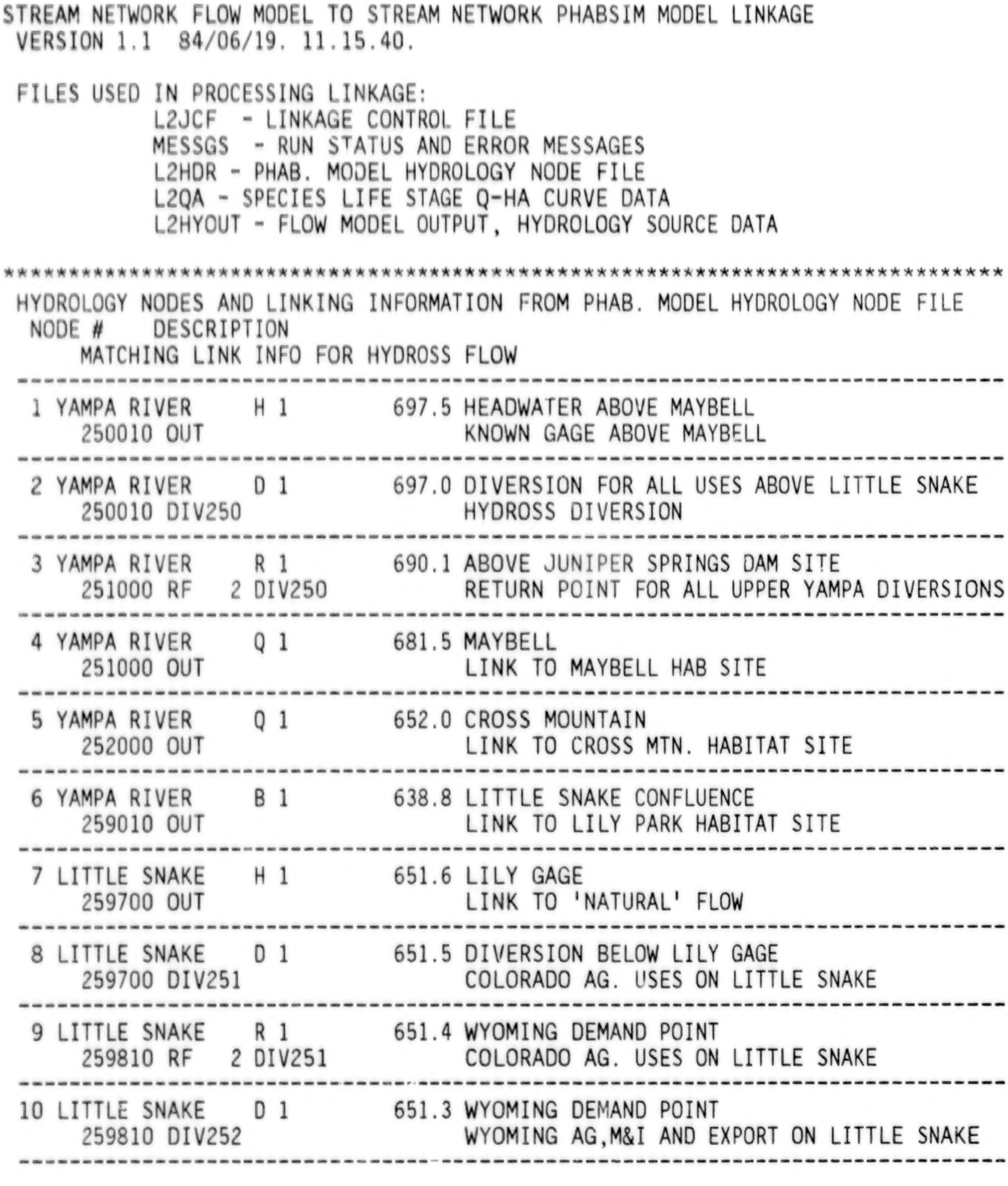
- Life stage name
- Minimum area encountered
- When minimum occurred (if more than one time, only first one is reported)
- Average area encountered
- Maximum area encountered
- When maximum encountered (if more than one time, only first one is reported)
- Percentage of total area contributed by each node

```
SQUAADU
HYDROSS TO MICRO-HABITAT LINK; FULL TEST OF CAPABILITY
SQUAWFISH ADULT      UNITS = CY:KSQFT        84/06/19. 11.37.55.
SUM            11965   14205732404000940990773573594 1.E-99 1.E-99    CY:KSQFT
SUM            11965   2 1.E-99 1.E-9941394634167372402156438995OO    CY:KSQFT
SUM            11966   13752307383303138314213856838 1.E-99 1.E-99    CY:KSQFT
SUM            11966   2 1.E-99 1.E-994188181407949238630734115587    CY:KSQFT
SUM            11967   14184346408945638896803945543 1.E-99 1.E-99    CY:KSQFT
SUM            11967   2 1.E-99 1.E-994313566433729542239614361519    CY:KSQFT
SUM            11968   14321651426592239502774016707 1.E-99 1.E-99    CY:KSQFT
SUM            11968   2 1.E-99 1.E-994336998404696340466164215921    CY:KSQFT
SUM            11969   14113921411097141959613410216 1.E-99 1.E-99    CY:KSQFT
SUM            11969   2 1.E-99 1.E-994043199384010339147814269587    CY:KSQFT
SUM            11970   13801999384227638749464003941 1.E-99 1.E-99    CY:KSQFT
SUM            11970   2 1.E-99 1.E-994074385392865637866563810766    CY:KSQFT
SUM            11971   13771476382226639035903770185 1.E-99 1.E-99    CY:KSQFT
SUM            11971   2 1.E-99 1.E-994021433399168841309384385825    CY:KSQFT
SUM            11972   14050732418349140745653866041 1.E-99 1.E-99    CY:KSQFT
SUM            11972   2 1.E-99 1.E-994225684413043041389284359108    CY:KSQFT
SUM            11973   14364527439971240490343909790 1.E-99 1.E-99    CY:KSQFT
SUM            11973   2 1.E-99 1.E-994099093404791240492644140067    CY:KSQFT
--EOR--
SQUAYOY
HYDROSS TO MICRO-HABITAT LINK; FULL TEST OF CAPABILITY
SQUAWFISH YOY        UNITS =CY:KSQFT        84/06/19. 11.37.58.
SUM            21965   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99  44134    CY:KSQFT
SUM            21965   2  74827 139294 300572 1.E-99 1.E-99 1.E-99    CY:KSQFT
SUM            21966   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 224200    CY:KSQFT
SUM            21966   2 259342 544581 653042 1.E-99 1.E-99 1.E-99    CY:KSQFT
SUM            21967   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99  53536    CY:KSQFT
SUM            21967   2  72999 227118 280703 1.E-99 1.E-99 1.E-99    CY:KSQFT
SUM            21968   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99  70660    CY:KSQFT
SUM            21968   2 153168 194411 275859 1.E-99 1.E-99 1.E-99    CY:KSQFT
SUM            21969   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 107952    CY:KSQFT
SUM            21969   2 177120 249738 438049 1.E-99 1.E-99 1.E-99    CY:KSQFT
SUM            21970   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99  78104    CY:KSQFT
SUM            21970   2 194112 470095 595568 1.E-99 1.E-99 1.E-99    CY:KSQFT
SUM            21971   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99  46613    CY:KSQFT
SUM            21971   2 113088 252724 483743 1.E-99 1.E-99 1.E-99    CY:KSQFT
SUM            21972   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99  32890    CY:KSOFT
SUM            21972   2 100037 250342 690251 1.E-99 1.E-99 1.E-99    CY:KSQFT
SUM            21973   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99  82000    CY:KSQFT
SUM            21973   2 151389 201049 267562 1.E-99 1.E-99 1.E-99    CY:KSQFT
```

Figure 5. Example Habitat Time Series File (L2T10).

```
--EOR--
SQUASPA
HYDROSS TO MICRO-HABITAT LINK; FULL TEST OF CAPABILITY
SQUAWFISH SPAWNING   UNITS = CY:KSQFT        84/06/19. 11.38.06.
SUM             51965   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99  18434    CY:KSQFT
SUM             51965   2  27269  30627 1.E-99 1.E-99 1.E-99 1.E-99    CY:KSQFT
SUM             51966   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99  28962    CY:KSQFT
SUM             51966   2  19521   9806 1.E-99 1.E-99 1.E-99 1.E-99    CY:KSQFT
SUM             51967   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99  21273    CY:KSQFT
SUM             51967   2  28257  19502 1.E-99 1.E-99 1.E-99 1.E-99    CY:KSQFT
SUM             51968   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99  17392    CY:KSQFT
SUM             51968   2  29324  30122 1.E-99 1.E-99 1.E-99 1.E-99    CY:KSQFT
SUM             51969   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99  25469    CY:KSQFT
SUM             51969   2  29805  21470 1.E-99 1.E-99 1.E-99 1.E-99    CY:KSQFT
SUM             51970   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99  18063    CY:KSQFT
SUM             51970   2  28039  24232 1.E-99 1.E-99 1.E-99 1.E-99    CY:KSQFT
SUM             51971   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99  18262    CY:KSQFT
SUM             51971   2  28491  17137 1.E-99 1.E-99 1.E-99 1.E-99    CY:KSQFT
SUM             51972   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99  25232    CY:KSQFT
SUM             51972   2  23438  14535 1.E-99 1.E-99 1.E-99 1.E-99    CY:KSQFT
SUM             51973   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99  20596    CY:KSQFT
SUM             51973   2  27689  25010 1.E-99 1.E-99 1.E-99 1.E-99    CY:KSQFT
--EOR--
```

Figure 5. (Concluded)



```
STREAM NETWORK FLOW MODEL TO STREAM NETWORK PHABSIM MODEL LINKAGE
 VERSION 1.1  84/06/19. 11.15.40.

 FILES USED IN PROCESSING LINKAGE:
            L2JCF  - LINKAGE CONTROL FILE
            MESSGS  - RUN STATUS AND ERROR MESSAGES
            L2HDR - PHAB. MODEL HYDROLOGY NODE FILE
            L2QA - SPECIES LIFE STAGE Q-HA CURVE DATA
            L2HYOUT - FLOW MODEL OUTPUT, HYDROLOGY SOURCE DATA

********************************************************************************
 HYDROLOGY NODES AND LINKING INFORMATION FROM PHAB. MODEL HYDROLOGY NODE FILE
  NODE #    DESCRIPTION
      MATCHING LINK INFO FOR HYDROSS FLOW
--------------------------------------------------------------------------------
  1 YAMPA RIVER     H 1         697.5 HEADWATER ABOVE MAYBELL
      250010 OUT                      KNOWN GAGE ABOVE MAYBELL
--------------------------------------------------------------------------------
  2 YAMPA RIVER     D 1         697.0 DIVERSION FOR ALL USES ABOVE LITTLE SNAKE
      250010 DIV250                   HYDROSS DIVERSION
--------------------------------------------------------------------------------
  3 YAMPA RIVER     R 1         690.1 ABOVE JUNIPER SPRINGS DAM SITE
      251000 RF    2 DIV250           RETURN POINT FOR ALL UPPER YAMPA DIVERSIONS
--------------------------------------------------------------------------------
  4 YAMPA RIVER     Q 1         681.5 MAYBELL
      251000 OUT                      LINK TO MAYBELL HAB SITE
--------------------------------------------------------------------------------
  5 YAMPA RIVER     Q 1         652.0 CROSS MOUNTAIN
      252000 OUT                      LINK TO CROSS MTN. HABITAT SITE
--------------------------------------------------------------------------------
  6 YAMPA RIVER     B 1         638.8 LITTLE SNAKE CONFLUENCE
      259010 OUT                      LINK TO LILY PARK HABITAT SITE
--------------------------------------------------------------------------------
  7 LITTLE SNAKE    H 1         651.6 LILY GAGE
      259700 OUT                      LINK TO 'NATURAL' FLOW
--------------------------------------------------------------------------------
  8 LITTLE SNAKE    D 1         651.5 DIVERSION BELOW LILY GAGE
      259700 DIV251                   COLORADO AG. USES ON LITTLE SNAKE
--------------------------------------------------------------------------------
  9 LITTLE SNAKE    R 1         651.4 WYOMING DEMAND POINT
      259810 RF    2 DIV251           COLORADO AG. USES ON LITTLE SNAKE
--------------------------------------------------------------------------------
 10 LITTLE SNAKE    D 1         651.3 WYOMING DEMAND POINT
      259810 DIV252                   WYOMING AG,M&I AND EXPORT ON LITTLE SNAKE
--------------------------------------------------------------------------------
```

Figure 6. Example of the MESSGS output file.

```
11 LITTLE SNAKE    R 1         651.2 MOUTH AT YAMPA CONFLUENCE
     260000 RF   2 DIV252            WYOMING AG., M&I AND EXPORT ON LITTLE SNAKE
--------------------------------------------------------------------------------
12 LITTLE SNAKE    T 1         638.8 MOUTH AT YAMPA CONFLUENCE
     260000 OUT                      LINK TO MANTLE,CLEOPATRA & BOX ELDER HAB SITES
--------------------------------------------------------------------------------
13 YAMPA RIVER     J           638.8 BELOW LITTLE SNAKE CONFLUENCE
--------------------------------------------------------------------------------
14 YAMPA RIVER     C 1         627.5 LILY PARK
     260099 OUT                      LINK TO MANTLE RANCH HABITAT SITE
--------------------------------------------------------------------------------
15 YAMPA RIVER     C 1         585.7 HARDING HOLE
     260099 OUT                      LINK TO CLEOPATRA'S COUCH HABITAT SITE
--------------------------------------------------------------------------------
16 YAMPA RIVER     B 1         556.7 GREEN RIVER CONFLUENCE

--------------------------------------------------------------------------------
17 GREEN RIVER     O 1         423.2 OURAY REFUGE STUDY SITE
     261050 OUT                      LINK TO OURAY HABITAT SITE

END OF ERROR CHECKING IN HYDROLOGY NODE FILE

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * 
CHECKING HYDROSS NETWORK FOR REQUESTED LINKING INFORMATION.
HYDROSS FLOW ASSUMED TO BE IN CMS. THIS LINK CONVERTS TO CFS.

THE HYDROSS NETWORK CONTAINS THE FOLLOWING STATIONS
--------------------------------------------------------------------------------
211200  GREEN RIVER NAT FLOW AT FONTENELLE
--------------------------------------------------------------------------------
216510  GREEN RIVER AT FONTENELLE RESERVOIR
--------------------------------------------------------------------------------
220010  GREEN RIVER DEMAND PT BLW FONTENELLE RES
--------------------------------------------------------------------------------
221010  GREEN RIVER DEMAND POWER M&I F&W
--------------------------------------------------------------------------------
225010  GREEN RIVER DEMAND ABV FLAMING GORGE
--------------------------------------------------------------------------------
227010  GREEN RIVER LYMAN NAUGHTON
--------------------------------------------------------------------------------
234500  GREEN RIVER FLAMING GORGE RES
--------------------------------------------------------------------------------
240010  GREEN RIVER ABV YAMPA CONFLUENCE
--------------------------------------------------------------------------------
250010  YAMPA RIVER NAT FLOW NEAR MAYBELL CO
--------------------------------------------------------------------------------
251000  YAMPA RIVER AT JUNIPER SPRNGS DAMSITE
--------------------------------------------------------------------------------
```

Figure 6. (Continued)

```
252000  YAMPA RIVER AT X-MT DAMSITE
--------------------------------------------------------------------------------
259010  YAMPA RIVER ABV LITTLE SNAKE CONFLUENCE
--------------------------------------------------------------------------------
259700  LITTLE SNAKE RIVER NAT FLOW NEAR LILY CO
--------------------------------------------------------------------------------
259810  LITTLE SNAKE RIVER WYO DEMAND PT
--------------------------------------------------------------------------------
260000  LITTLE SNAKE RIVER AT MOUTH
--------------------------------------------------------------------------------
260010  YAMPA RIVER BLW LITTLE SNAKE CONFLUENCE
--------------------------------------------------------------------------------
260099  YAMPA RIVER AT GREEN RIVER CONFLUENCE
--------------------------------------------------------------------------------
260910  GREEN RIVER BLW YAMPA CON (SPLIT MT GORG
--------------------------------------------------------------------------------
260950  GREEN RIVER DEMAND NEAR VERNAL UTAH
--------------------------------------------------------------------------------
261000  GREEN RIVER NEAR JENSEN UTAH
--------------------------------------------------------------------------------
261050  GREEN RIVER AT OURAY HABITAT SITE
--------------------------------------------------------------------------------
261099  GREEN ABV DUCHESNE CONFLUENCE

END OF CHECKING HYDROSS NETWORK FOR REQUESTED LINKING INFORMATION

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
HYDROSS FLOW DATA FROM FILE L2HYOUT A/O DATE: MAY 25,1984 1453

END OF PROCESSING FLOWS FROM HYDROSS

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
CHECKING SPECIES/LIFE STAGE Q-WUA DATA FILE:
NODE#     DESCRIPTION
    LIFE STAGE DATA (MONTHS CORRESPOND TO HYDROSS INPUT)

FLOW/HABITAT VALUE FILE FOR UPPER COLORADO TEST ASSEMBLED BY BARTHOLOW MAY 84

--------------------------------------------------------------------------------
14 YAMPA RIVER     C 1        627.5 LILY PARK
   1 SQUAWFISH YOY         HAS  28 FLOW DATA POINTS
       MONTHS = 000001111000  THRESHOLD =      0.00  DISTANCE =     10.00 MI.

--------------------------------------------------------------------------------
14 YAMPA RIVER     C 1        627.5 LILY PARK
   2 SQUAWFISH ADULT       HAS  28 FLOW DATA POINTS
       MONTHS = 111100001111  THRESHOLD =      0.00  DISTANCE =     10.00 MI.
--------------------------------------------------------------------------------
```

Figure 6. (Continued)

```
16 YAMPA RIVER     B 1        556.7 GREEN RIVER CONFLUENCE
   1 SQUAWFISH YOY         HAS  28 FLOW DATA POINTS
       MONTHS = 000001111000  THRESHOLD =       0.00  DISTANCE =     10.00 MI.

--------------------------------------------------------------------------------
16 YAMPA RIVER     B 1        556.7 GREEN RIVER CONFLUENCE
   2 SQUAWFISH ADULT       HAS  28 FLOW DATA POINTS
       MONTHS = 111100001111  THRESHOLD =       0.00  DISTANCE =     10.00 MI.

--------------------------------------------------------------------------------
 4 YAMPA RIVER     Q 1        681.5 MAYBELL
   2 SQUAWFISH ADULT       HAS   6 FLOW DATA POINTS
       MONTHS = 111100001111  THRESHOLD =       0.00  DISTANCE =     13.00 MI.

--------------------------------------------------------------------------------
 4 YAMPA RIVER     Q 1        681.5 MAYBELL
   1 SQUAWFISH YOY         HAS   5 FLOW DATA POINTS
       MONTHS = 000001111000  THRESHOLD =       0.00  DISTANCE =     13.00 MI.

--------------------------------------------------------------------------------
15 YAMPA RIVER     C 1        585.7 HARDING HOLE
   5 SQUAWFISH SPAWNING    HAS   8 FLOW DATA POINTS
       MONTHS = 000001110000  THRESHOLD =       0.00  DISTANCE =       .19 MI.

--------------------------------------------------------------------------------
17 GREEN RIVER     O 1        423.2 OURAY REFUGE STUDY SITE
   2 SQUAWFISH ADULT       HAS  28 FLOW DATA POINTS
       MONTHS = 111100001111  THRESHOLD =       0.00  DISTANCE =     15.00 MI.

--------------------------------------------------------------------------------
17 GREEN RIVER     O 1        423.2 OURAY REFUGE STUDY SITE
   1 SQUAWFISH YOY         HAS  28 FLOW DATA POINTS
       MONTHS = 000001111000  THRESHOLD =       0.00  DISTANCE =     15.00 MI.

--------------------------------------------------------------------------------
16 YAMPA RIVER     B 1        556.7 GREEN RIVER CONFLUENCE
   2 SQUAWFISH ADULT       HAS  27 FLOW DATA POINTS
       MONTHS = 111100001111  THRESHOLD =       0.00  DISTANCE =      4.50 MI.

--------------------------------------------------------------------------------
16 YAMPA RIVER     B 1        556.7 GREEN RIVER CONFLUENCE
   1 SQUAWFISH YOY         HAS  27 FLOW DATA POINTS
       MONTHS = 000001111000  THRESHOLD =       0.00  DISTANCE =      4.50 MI.

--------------------------------------------------------------------------------
```

Figure 6. (Continued)

```
END OF CHECKING SPECIES/LIFE STAGE Q-WUA DATA FILE
YOU HAVE  17 ENTRIES AND   7 UNIQUE LIFE STAGE(S).

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
PROCESSING YOUR JOB CONTROL FILE:

    HYDROSS TO MICRO-HABITAT LINK; FULL TEST OF CAPABILITY
    CY: SQFT    WILL DEFINE TOTAL AREA IN NETWORK
     UNITS = CY: SQFT
    FIRST YEAR =   65
    LAST YEAR  =   78
    MONTHS = 11111111111
    NUMBER OF NODES =     7
    NODES LIST =    4    5    6   14   15   16   17
    NUMBER OF LIFES =   10
    LIFE STAGE LIST =    1    2    3    4    5    6    7    8    9   10
    TAPE10 DATA FMT =    0

END OF PROCESSING JOB CONTROL FILE.

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
BEGINNING TO GENERATE HABITAT TIME SERIES      84/06/19. 11.17.34.

        1 SQUAWFISH YOY
           = SQUAYOY
        2 SQUAWFISH ADULT
           = SQUAADU
        3 SQUAWFISH CYOY
           = SQUACYO
        4 SQUAWFISH CADULT
           = SQUACAD
        5 SQUAWFISH SPAWNING
           = SQUASPA
        6 SQUAWFISH DEP/FERT
           = SQUADEP
        7 SQUAWFISH STG/REST
           = SQUASTG

END OF HABITAT TIME SERIES GENERATION
DATA IS ON FILE "L2T10"

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
BEGIN THE REPORT SECTION

=================================================================================
```

Figure 6. (Continued)

```
   1 SQUAWFISH YOY
          MINIMUM AREA ENCOUNTERED =    32971.
              IN YEAR 1972 MONTH  6
         AVERAGE AREA =    70058.  SQFT   PER MONTH
          MAXIMUM AREA ENCOUNTERED =   919592.
              IN YEAR 1975 MONTH  9
 NODE  PERCENT  DESCRIPTION
--------------------------------------------------------------------------------
    4    13      YAMPA RIVER     Q 1        681.5 MAYBELL
   14     2      YAMPA RIVER     C 1        627.5 LILY PARK
   16    11      YAMPA RIVER     B 1        556.7 GREEN RIVER CONFLUENCE
   17    72      GREEN RIVER     O 1        423.2 OURAY REFUGE STUDY SITE
       -------
        100%

=================================================================================
   2 SQUAWFISH ADULT
          MINIMUM AREA ENCOUNTERED =  3439511.
              IN YEAR 1969 MONTH  4
         AVERAGE AREA =  1016297.  SQFT   PER MONTH
          MAXIMUM AREA ENCOUNTERED =  4401666.
              IN YEAR 1973 MONTH  2
 NODE  PERCENT  DESCRIPTION
---------------------------------------------------------------------------------
    4     2      YAMPA RIVER     Q 1        681.5 MAYBELL
   14     0      YAMPA RIVER     C 1        627.5 LILY PARK
   16    15      YAMPA RIVER     B 1        556.7 GREEN RIVER CONFLUENCE
   17    81      GREEN RIVER     O 1        423.2 OURAY REFUGE STUDY SITE
       -------
        100%
=================================================================================
   5 SQUAWFISH SPAWNING
          MINIMUM AREA ENCOUNTERED =     2670.
              IN YEAR 1977 MONTH  8
         AVERAGE AREA =    21886.  SQFT   PER MONTH
          MAXIMUM AREA ENCOUNTERED =    30628.
              IN YEAR 1965 MONTH  8
 NODE  PERCENT  DESCRIPTION
--------------------------------------------------------------------------------
   15   100      YAMPA RIVER     C 1        585.7 HARDING HOLE
       -------
        100%

THAT'S ALL FOLKS -- NORMAL END OF JOB


THERE WERE   0 FATAL ERROR(S) IN THIS LINKRUN
       AND   1 WARNING ERROR(S)
```

Figure 6. (Concluded)

3.5 Defaults

The only default conditions used in LNKQ2H pertain to the job control file. If that file is unreadable for some reason, the defaults are to use the first and last years of HYDROSS data, use all months, use all nodes from the hydrology node file (L2HDR), and use all life stages from the habitat vs. flow data file (L2QA). The default habitat time series data file (L2HTS) format is USGS.

4.0 RELATED SOFTWARE

4.1 Precursors

There are at least two precursors to running LNKQ2H: PHABSIM and HYDROSS. Both are well beyond the scope of this documentation. However, there are a few hints to be passed along.

HYDROSS. When setting up your HYDROSS data set you must remember to account for the physical habitat sites in the network description. General guidelines would call for establishing a station wherever there is likely to be a change in flow of greater than 10 percent through a habitat site. In this way, accurate translation of flow to habitat value may be retained.

PHABSIM. Aside from assembling all of the habitat vs. flow data files (known as TAPE8s in PHABSIM) into a single file, there remains at least one important task. The upper and lower bounds of each curve should be examined for their ability to handle the extremes of yearly flows likely to be encountered in a HYDROSS run. LNKQ2H does no curve extrapolation as do some other PHABSIM routines. If a flow is encountered outside the bounds of a life stage's curve, the habitat value is set to zero. A warning message is provided, but it is the user's responsibility to provide reasonable extrapolations or accept the consequences. It was felt that this approach was more prudent than extrapolation, because pure mathematical extrapolation is often not hydrologically or biologically acceptable.

Occasionally LNKQ2H may be used in concert with the temperature model. Normally this will not be the case, since LNKQ2T bypasses the need for LNKQ2H. However, should you have occasion to be using the temperature model, you will want to set up your hydrology node file (L2HDR) to copy the node descriptors exactly.

4.2 Postcursors

We have made much use of PHABSIM plotting and duration analysis programs to continue the analysis of the results of LNKQ2H. Typically, you would use RGET1 to extract single life stages as records from the habitat time series file (L2HTS) to be used as input to programs such as LPTDUR and LPTHTS. In the future, links to the Effective Habitat Time Series programs should be performed in the same way.

4.3 Alternative Methods

There are no alternatives at this time.

5.0 LIMITATIONS

5.1 Accuracy

LNKQ2H contains only one mathematical relationship. The interpolation to calculate WUA given the flow is strictly linear. All constants to change units have at least four decimal places.

5.2 Known Deficiencies

LNKQ2H has at least one bug. For unknown reasons, the program must be compiled with the FTN5 debug option (DB) turned on. Without the DB, you will get an 'Over Indexed Array' message. One other consequence apparently related to this problem is the fact that you may get a run summary that shows at least one warning error even though there may be none in the output listing (MESSGS).

There is a less severe error condition that arises should there be an improper syntax in the hydrology node file (L2HDR). This arises if you fail to have a 'J' node following a pair of 'B' and 'T' nodes. Also, you must end in an 'E' node.

5.3 Assumptions

LNKQ2H assumes that the HYDROSS flows are in units of cubic meters per month, that stream lengths are in miles, and that the WUA units are per 1000 feet of stream. Beyond these, units-in will always equal units-out; though the print out may refer to constant units.

5.4 Constraints

Current program limits are listed as follows. However, these limits may be changed by altering the parameter statements in the source code and recompiling. If recompiling, please see Section 5.2.

Maximum Number of Nodes	25
Maximum Number of Life Stages	10
Maximum Number of Points in HA vs. Q Curve	30
Maximum Number of HYDROSS Stations	100
Maximum Number of Structures	30

6.0 MESSAGES

Messages are divided into two categories, warning and fatal. These are listed separately, approximately in the order in which they might be encountered. In general, warning messages will not cause program termination; the job will do its best to continue. Fatal errors, however, will cause either immediate or delayed job termination, depending on the circumstances. The output file (OUTPUT) will provide a run summary for these messages.

6.1 Warning Messages

a. *** WARNING *** THE NODE xxx WAS ENCOUNTERED IN YOUR Q-WUA DATA FILE, BUT NOT FOUND IN YOUR HYDROLOGY NODE FILE. PROCESSING SKIPS THIS NODE COMPLETELY.

You may feel free to have a large data base of curves and not refer to them in your linkage.

b. *** WARNING *** BAD SPECIES LIFE STAGE xxx FOUND IN FILE. I WILL TRY TO RECOVER.

Check your curve data file (L2QA) for incorrect number of title lines, no **********, or something like that.

c. *** WARNING *** EXPECTED A NEW LIFE STAGE BUT FOUND AN END OF FILE. I WILL TRY TO CONTINUE.

Check card sequence in curve data file (L2QA).

d. *** WARNING *** TOO MANY UNIQUE LIFE STAGES ENCOUNTERED. I CAN ONLY HANDLE xxx. I WILL CONTINUE WITH WHAT I HAVE.

Either remove unessential life stages or recompile program with new parameters.

e. *** WARNING *** TOO MANY POINTS IN CURVE. I ONLY HAVE ROOM FOR xxx. I WILL TRY TO RECOVER.

Either remove unessential points or recompile program with new parameters.

f. *** WARNING *** FLOW DATA NOT INCREASING. CHECK DATA FILE FOR flow IN node.

Succeeding flows must increase from record to record to be able to interpolate properly. Check your L2QA data file.

g. *** WARNING *** THIS NODE HAS NO FLOW-WUA DATA POINTS. I WILL TRY TO CONTINUE.

h. *** WARNING *** THE FIRST YEAR REQUESTED xxx IS OUT OF BOUNDS OF HYDROSS DATA. I WILL START WITH THE FIRST YEAR OF HYDROSS INSTEAD.

You probably put 1960 instead of 60, for example.

i. *** WARNING *** THE LAST YEAR REQUESTED xxx IS GREATER THAN THE LAST YEAR OF HYDROSS DATA xxx. I WILL END WITH THE LAST YEAR OF HYDROSS INSTEAD.

Ditto above.

j. *** WARNING *** YOUR REQUESTED MONTHS WERE BLANK. YOU SHOULD SPECIFY THEM. I WILL PROCEED WITH THEM ALL TURNED ON.

Check the format for the species line in file L2QA.

k. *** WARNING *** THE NUMBER OF NODES REQUESTED IS xxx. I NEED BETWEEN 1 AND xxx. I WILL PROCEED WITH THE MAXIMUM ALLOWED.

l. *** WARNING *** NODE REQUESTED xxx IS OUT OF BOUNDS.

In other words, you asked for a node number to be aggregated that does not exist. Probably a typo or wrong column in L2JCF.

m. *** WARNING *** THE NUMBER OF LIFE STAGES REQUESTED IS xxx. I NEED BETWEEN 1 AND xxx. I WILL PROCEED WITH THE MAXIMUM ALLOWED.

n. *** WARNING *** LIFE STAGE REQUESTED xxx IS OUT OF BOUNDS.

Probably a typo or wrong column in L2JCF.

o. *** WARNING *** ILLEGAL FORMAT REQUESTED. I WILL DEFAULT TO 0.

Probably a typo or wrong column in L2JCF.

p. *** WARNING *** UNEXPECTED END FOUND ON JOB CONTROL FILE. I WILL USE DEFAULTS FOR THE MISSING VALUES.

q. *** WARNING *** FOR life stage AT node, FLOW OF xxx IS BELOW LOWEST FLOW IN Q-HA RELATIONSHIP.

Zero will be used. You should supply interpolation.

r. *** WARNING *** FOR life stage AT node, FLOW OF xxx IS GREATER THAN HIGHEST FLOW IN Q-HA CURVE.

Zero will be used. You should supply interpolation.

s. YEAR = xxx MONTH = xxx FLOW OF xxx IS BELOW YOUR THRESHOLD OF xxx.

This relates to the threshold value on your species line in L2QA data file.

t. *** WARNING *** FOUND xxx INSTEAD OF PROPER UNITS.

Consult units tables for legitimate options.

6.2 Fatal Messages

a. FATAL ERROR: THE NUMBER OF HYDROLOGY NODES: xxx EXCEEDS THE ALLOWED MAXIMUM xxx.

   Reduce the number of nonrequired nodes or recompile the program.

b. FATAL ERROR: UNEXPECTED END FOUND ON PHAB. MODEL HYDROLOGY NODE FILE. CHECK IF FILE EXISTS AND IS LOCAL, THEN RERUN LINKAGE.

c. FATAL ERROR: MATCHING CONTROL PT xxx HAS NO EQUIVALENT IN THE HYDROSS NETWORK. REVIEW THE HYDROSS NETWORK AND PHAB. MODEL HYDROLOGY NODE FILES.

   In other words, you probably mistyped a link to HYDROSS station number.

d. FATAL ERROR: A RESERVOIR WAS EXPECTED AT STATION xxx IN HYDROSS BUT NOT FOUND. REVIEW THE HYDROSS NETWORK AND PHAB. MODEL HYDROLOGY NODE FILES.

   You have an 'S' node referring to a HYDROSS station which is not a reservoir.

e. FATAL ERROR: A DIVERSION WAS EXPECTED AT STATION xxx IN HYDROSS BUT NOT FOUND. REVIEW THE HYDROSS NETWORK AND PHAB. MODEL HYDROLOGY NODE FILES.

f. FATAL ERROR: NO RETURN FLOW WAS FOUND IN THE HYDROSS NETWORK THAT MATCHES THIS REQUESTED RF: xxx

g. FATAL ERROR: UNEXPECTED END FOUND ON HYDROSS FILE WHILE PROCESSING RETURN FLOWS. THIS SHOULD NOT HAPPEN. GET HELP.

   You should not get this message.

h. FATAL ERROR: AN ERROR OCCURED WHILE WRITING TO IOSCR. THIS SHOULD NOT HAPPEN. ERR NR WAS xxx. GET HELP.

i. FATAL ERROR: DID NOT GET SUFFICIENT DATA FROM LIFE STAGE FILE TO CONTINUE WITH PROCESSING.

   You must have at least one valid node/life stage with at least one data point. Chances are you goofed on this data file (L2QA).

j. FATAL ERROR: PROBLEM WITH SCRATCH FILE IN SUBROUTINE WRITE10.

   Highly unlikely. Computer is probably going down.

7.0 TIME & COST

A typical run of 7 nodes, 7 life stages, and all months of 20 years would take about 60 seconds and cost about $8 in normal daytime 1200 baud service. Costs are reduced substantially in batch mode to $4.25, but may be expected to take up to 5 minutes, depending on the load.

These estimates, of course, do not include time to set up and debug data files. Though difficult to estimate, please allow up to 2 days to really get started. This ignores setting up and running HYDROSS.

8.0 UNUSUAL APPLICATIONS -- None.

9.0 POSSIBLE MODIFICATIONS -- None.

10.0 SUPPLEMENTAL MATERIAL

See also the PHABSIM, HYDROSS, and TEMPERATURE MODEL documentation. Also refer to documentation for LNKQ2T.

11.0 ACKNOWLEDGEMENTS

Development of this program was paid for by U.S. Fish and Wildlife Service, Region 6 (Denver).

APPENDIX C

TITLE -- LNKT2H (Temperature Model to Habitat Model) Version 1.2

AUTHORS -- John Bartholow
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U.S. Fish & Wildlife Service
Western Energy and Land Use Team
April 1985

1.0 INTRODUCTION

This program provides a linkage between a monthly stream network temperature model and the Physical Habitat Simulation System (PHABSIM) developed by the Cooperative Instream Flow Service Group, U.S. Fish and Wildlife Service.

This linkage will match the flows provided by the temperature model with the habitat vs. flow relationship data from PHABSIM for one or more life stages at one or more geographic locations. It will then modify that habitat value with temperatures generated by the temperature model to produce a networkwide habitat time series for each unique life stage. The temperature-induced habitat modification is accomplished with the use of a temperature vs. suitability index relationship for each life stage.

Part of the temperature to habitat linkage, LNKT2H, will also calculate the accumulation of degree-days over time at user-specified geographic nodes. Degree-days are important in the study of aquatic systems, especially as they relate to certain biological processes such as egg maturation and growth.

Input data are provided by the temperature model and the primary output is in the form of a U.S. Geological Survey (USGS) or Northwest Data Center (NWDC) monthly time series data file. The time series data may then be used in subsequent time series manipulations such as plots and duration analyses.

This program is really more than a linkage, but less than a real stream network habitat model. It is less than a habitat model because there remain numerous subjective and objective judgements after one has the results in hand. This program is a member of a family of programs in the network habitat analysis family. This group includes:

LNKQ2T - HYDROSS to TEMPERATURE MODEL
LNKT2H - TEMPERATURE to HABITAT MODEL (this program)
LNKQ2H - HYDROSS to HABITAT MODEL
LNKG2H - GAGE DATA to HABITAT MODEL
LNKT2TS - TEMPERATURE TO TIME SERIES PROGRAM

1.1 Execution Procedure

This program must be run in BATCH mode.

```
/JOB
SNHAB,P2.
/USER
/CHARGE,*.
COMMENT. P2 = DEFAULT
COMMENT. P3 = 6PM TO 6AM
COMMENT. P5 = SAT, SUN & HOLIDAYS
PURGE,QOUT/NA.
DEFINE,QOUT.
ATTACH,KTRNSPT = temperature model output file.
GET,L3JCF = job control file.
GET,L3QA = wua-flow data file.
GET,L3TSI = temperature - SI data file.
GET,LNKT2H.
LNKT2H.
REWIND,*.
COPY,OUTPUT,QOUT.
COPY,MESSGS,QOUT.
COPYSBF,L3DDTS,QOUT.
COPYSBF,L3HTS,QOUT.
REWIND,QOUT.
COPY,QOUT,QQ.
DAYFILE,QA.
REPLACE,QA.
EXIT.
STATUS,F.
REWIND,*.
COPY,OUTPUT,QOUT.
COPY,MESSGS,QOUT.
COPYSBF,L3DDTS,QOUT.
COPYSBF,L3HTS,QOUT.
COPY,PMDUMP,QOUT.
DAYFILE,QAA.
REPLACE,QAA.
```

2.0 APPLICATION

It is assumed that you have run the temperature model with a node network sufficient to match the habitat site requirements necessary for an adequate habitat analysis. If so, this linkage operates as follows:

2.1 Description of Logic

From a user's perspective, LNKT2H does the following:

2.1.1 Step one opens and rewinds all files necessary for operation (Figure 1).

BLANK PAGE

BLANK PAGE

BLANK PAGE

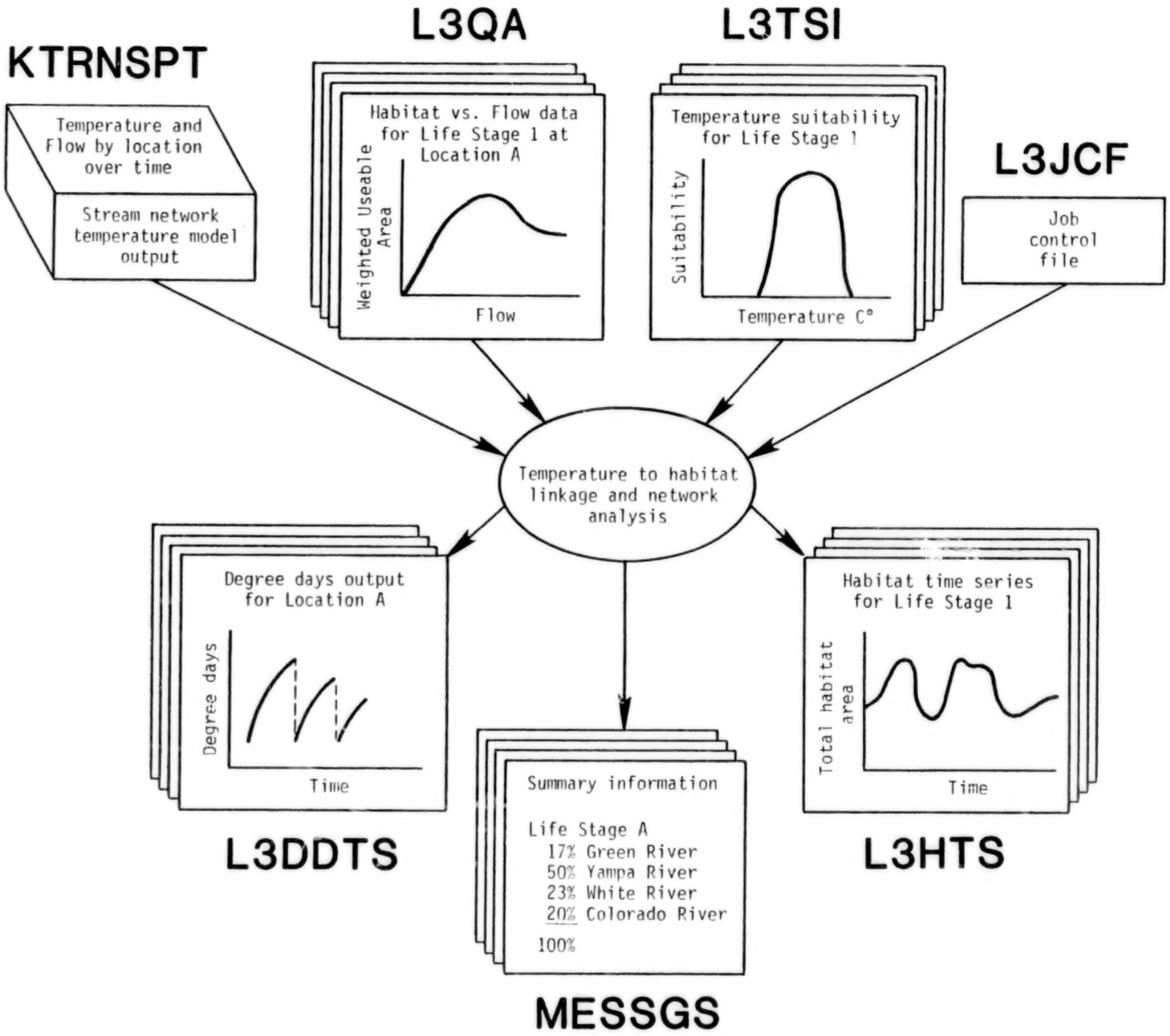

KTRNSPT
Temperature and Flow by location over time
Stream network temperature model output
L3QA
Habitat vs. Flow data for Life Stage 1 at Location A
Weighted Useable Area
Flow
L3TSI
Temperature suitability for Life Stage 1
Suitability
Temperature C°
L3JCF
Job control file
Temperature to habitat linkage and network analysis
Degree days output for Location A
Degree days
Time
L3DDTS
Summary information
Life Stage A
17% Green River
50% Yampa River
23% White River
20% Colorado River
100%
MESSGS
Habitat time series for Life Stage 1
Total habitat area
Time
L3HTS

Figure 1. Essential input and output files for temperature model to habitat model linkage.

Input:

- KTRNSPT - Temperature model random access output file, must be local.
- L3QA - Habitat vs. Flow data file, must be local.
- L3TSI - Temperature Suitability Index data file, optional.
- L3JCF - Job control file, must be local.

Output:

- OUTPUT - For brief program termination messages.
- MESSGS - For run status, error messages and summary report. This file is rewound at the end of the run.
- L3HTS - For the habitat time series data. This file is rewound at the end of the run.
- L3DDTS - For the degree-day time series.

2.1.2 Step two reads the temperature model output file from the transport model (KTRNSPT). This output file tells LNKT2H how many nodes, how many years, and how many time periods exist in the file. KTRNSPT is a binary, random access file and must not be edited using XEDIT.

The printed equivalent of this file may be obtained from the temperature model.

The routine will list to the MESSGS file the node names and their assigned node numbers.

2.1.3 Step three is to read the Weighted Usable Area Vs. Flow data file (L3QA). This file provides a habitat-flow relationship for each life stage at each geographic location. An example of L3QA is shown in Figure 2.

2.1.4 Step four is to read the Temperature Suitability Index (SI) data file (L3TSI). This routine reads the preference curve data for each species/life stage. An example of L3TSI is shown in Figure 3.

2.1.5 Step five is to read the Job Control File (L3JCF). The job file is the primary way to control most options in the program including which years, months, and life stages to use, how to interpret degree-days, and so on. An example of a job control file is shown in Figure 4.

```
FLOW/HABITAT VALUE FILE FOR UPPER COLORADO TEST ASSEMBLED BY BARTHOLOW MAY 84
YAMPA RIVER     Q 1        681.5 MAYBELL
DATA FROM PREWITT - JAN 1982 COMPLETION REPORT  YAMPA-WHITE PHYSICAL HABITAT INTERPRETED FROM GRAPH ON P.12
EXTRA TITLE LINE
SQUAWFISH                   111100001111         0.00      13.00
      DISCHARGE  ADULT
           0.0          0.0     ADDED BY BARTHOLOW
         200.00      1000.00
         500.00      2000.00
        1700.00      1000.00
       10000.00       500.00
       20000.00         0.00     ADDED BY BARTHOLOW
***************
YAMPA RIVER     Q 1        681.5 MAYBELL
DATA FROM PREWITT - JAN 1982 COMPLETION REPORT  YAMPA-WHITE PHYSICAL HABITAT INTERPRETED FROM GRAPH ON P.12
EXTRA TITLE LINE
SQUAWFISH                   000001111000         0.00      13.00
      DISCHARGE  YOY
           0.0          0.0     ADDED BY BARTHOLOW
         200.00      1000.00
         500.00       500.00
       10000.00       100.00
       20000.00         0.00     ADDED BY BARTHOLOW
***************
YAMPA RIVER     C 1        585.7 HARDING HOLE
DATA FROM PREWITT - JAN 1982 COMPLETION REPORT  YAMPA-WHITE PHYSICAL HABITAT INTERPRETED FROM GRAPH ON P.18
EXTRA TITLE LINE
SQUAWFISH                   000001110000         0.00       0.19
      DISCHARGE  SPAWNING
           0.00         0.00     ADDED BY BARTHOLOW
         250.00      7500.00
         400.00     13000.00
         600.00     19000.00
         800.00     24000.00
        1000.00     27000.00
        1200.00     31000.00
       22500.00         0.00     INTERPOLATED BY BARTHOLOW
```

Figure 2. Example flow - WUA data file (L3QA).

```
***************
GREEN RIVER      0 1        423.2 OURAY REFUGE STUDY SITE
1-20000 CFS.
DATA RUN BY BRUCE WAHLE -- MAY 1984
EXTRA TITLE LINE
SQUAWFISH                     111100001111          0.00      15.00
      DISCHARGE  ADULT
           1.00     43537.08
          25.00     39873.88
          50.00     44123.34
          75.00     44867.19
         100.00     44918.49
         200.00     44347.63
         300.00     43695.20
         400.00     41141.96
         500.00     39372.34
         600.00     38620.37
         700.00     37767.79
         800.00     37023.06
         900.00     36120.11
        1000.00     35907.06
        2000.00     39692.00
        3000.00     42165.00
        4000.00     44068.85
        5000.00     43754.18
        6000.00     41901.08
        7000.00     39663.41
        8000.00     39023.05
        9000.00     37158.67
       10000.00     35026.61
       11000.00     32402.88
       13000.00     30622.23
       15000.00     28340.38
       20000.00     15572.38
       24724.00         0.00     DATA INTERPOLATED BY WAHLE
```

Figure 2. (Concluded)

```
TEMPERATURE SUITABILITY CRITERIA FOR COLORADO SQUAWFISH
SQUAWFISH JV1            AVG  0.0
     00.0  0.0
     12.0  0.0
     15.0  0.2
     20.0  0.5
     25.0  1.0
     30.0  0.5
     32.0  0.0
**********
SQUAWFISH JV2            AVG  0.0
     00.0  0.0
     12.0  0.0
     15.0  0.2
     20.0  0.5
     25.0  1.0
     30.0  0.5
     32.0  0.0
**********
SQUAWFISH ADULT          AVG  0.0
     00.0  0.0
     12.0  0.0
     15.0  0.2
     20.0  0.5
     25.0  1.0
     30.0  0.5
     32.0  0.0
**********
SQUAWFISH YOY            AVG  0.0
     00.0  0.0
     12.0  0.0
     15.0  0.2
     20.0  0.5
     25.0  1.0
     30.0  0.5
     32.0  0.0
**********
```

Figure 3. Example temperature suitability (L3TSI) data file.

```
TEMP. MODEL TO MICRO-HABITAT LINK; TEST OF TEMP SI OPTION; PRE INDEX SWITCH
WY: SQFT    WILL DEFINE TOTAL AREA IN NETWORK
FIRST YEAR            72   59              (20X, 2I5)
LAST YEAR             82                   (20X, I5)
MONTHS              111111111111           (20X, A)
T COLORADO RIVER    H 1F      321.8        CAMEO GAGE
T COLORADO RIVER    D         320.2        IRRIGATION DEMAND
T COLORADO RIVER    B         286.4        GUNNISON RIVER, CONFLUENCE
T GUNNISON RIVER    H 1       298.0        GRAND JUNCTION, COLORADO
T GUNNISON RIVER    T         286.4        COLORADO RIVER CONFLUENCE
T COLORADO RIVER    J         286.4        GUNNISON RIVER JUNCTION
T COLORADO RIVER    R         257.4        IRRIGATION RETURN
T COLORADO RIVER    V 1S      217.2        STATE LINE GAGE
T COLORADO RIVER    E         200.0        TERMINAL POINT
**********
T SQUAWFISH STAGING
T SQUAWFISH DEPOSITION
T SQUAWFISH ADULT
T SQUAWFISH YOY
**********
TAPE10 DATA FMT        0     0 FOR USGS; 1 FOR NWDC    (20X, I5)
DD UPPER BOUND        99                   (20X, I5)
DD UPPER RESET        99                   (20X, I5)
DD BENCHMARK          12      AVG    0.0   (20X, I5, A5, F5.0)
DD LOWER RESET        12                   (20X, I5)
DD LOWER BOUND        12                   (20X, I5)
DD DAYS/TIME STEP     31  30  31  31  28  31  30  31  30  31  31  30
DD COUNTING METHOD  NONE                   (20X, A)
DD NORMALS YEAR       83                   (20X, I5)
DD DAYS TO RESET       5                   (20X, I5)
TEMP SAMPLE DIST    10.  KILOMETERS        (20X, F5.0)
```

Figure 4. Example job control file (L3JCF).

2.1.6 Step six is to calculate degree-days at specified nodes. The degree-day is a measure of the accumulated temperature surplus, in degrees Celsius, above an arbitrary temperature benchmark. The number of degree-days accumulated on any day is the difference between the temperature for that day and the arbitrary benchmark. Usually, the daily average (mean) temperature is used, but one might also elect to use the daily maximum or daily minimum temperature. Thus, if the daily average temperature was 15 degrees and the benchmark was 12 degrees, there would be an accumulation of 3 degree-days. If the daily mean temperature was 10 degrees, there would be an accumulation of -2 degree-days. Under some implementations, there may be no negative degree-days.

Calculation of degree-days in this linkage is kept entirely separate from preference curve calculations. Subsequent steps in analysis will be required to integrate differing criteria. For example, even if X number of degree-days are a prerequisite to successful spawning, this linkage will not reduce or alter the Weighted Usable Area (WUA) for spawning in any way. Further refinements and expansion of the linkage capabilities would be necessary to perform such analyses.

Similarly, fish may be in different geographic areas at different times accumulating degree-days. This linkage program will produce time series degree-day information for each desired node, but it makes no attempt to aggregate, average, or in any way perform a network analysis for degree-days. This is in contrast to the WUA analysis, which is a network summing. Further program refinements would be necessary to accommodate a network analysis for degree-days.

The degree-day routine finds the first applicable geographic node and initializes the time series output file. Next, the program cycles to the first user-requested year of data. Then the year's temperatures for each time step are determined from the temperature model data file. At the user's request, either maximum, average, or minimum mean daily temperatures for the time step are used. In addition, an adjustment by a constant may be made to whichever temperature is selected.

For each time step, temperatures are interpolated from the previous time step for the first half of the step and interpolated to the next time step for the last half of the step (Figure 5). In other words, if we are dealing with a monthly time step, daily temperatures for October are counted for October 1 to 15 by interpolating between the September temperature and the October temperature. Daily temperatures from October 16 to 31 are interpolated between October's temperature and November's temperature. Temperatures for the month prior to the specified year period and after the specified year period are taken from the normals, if necessary. If normals are not given, normals are calculated.

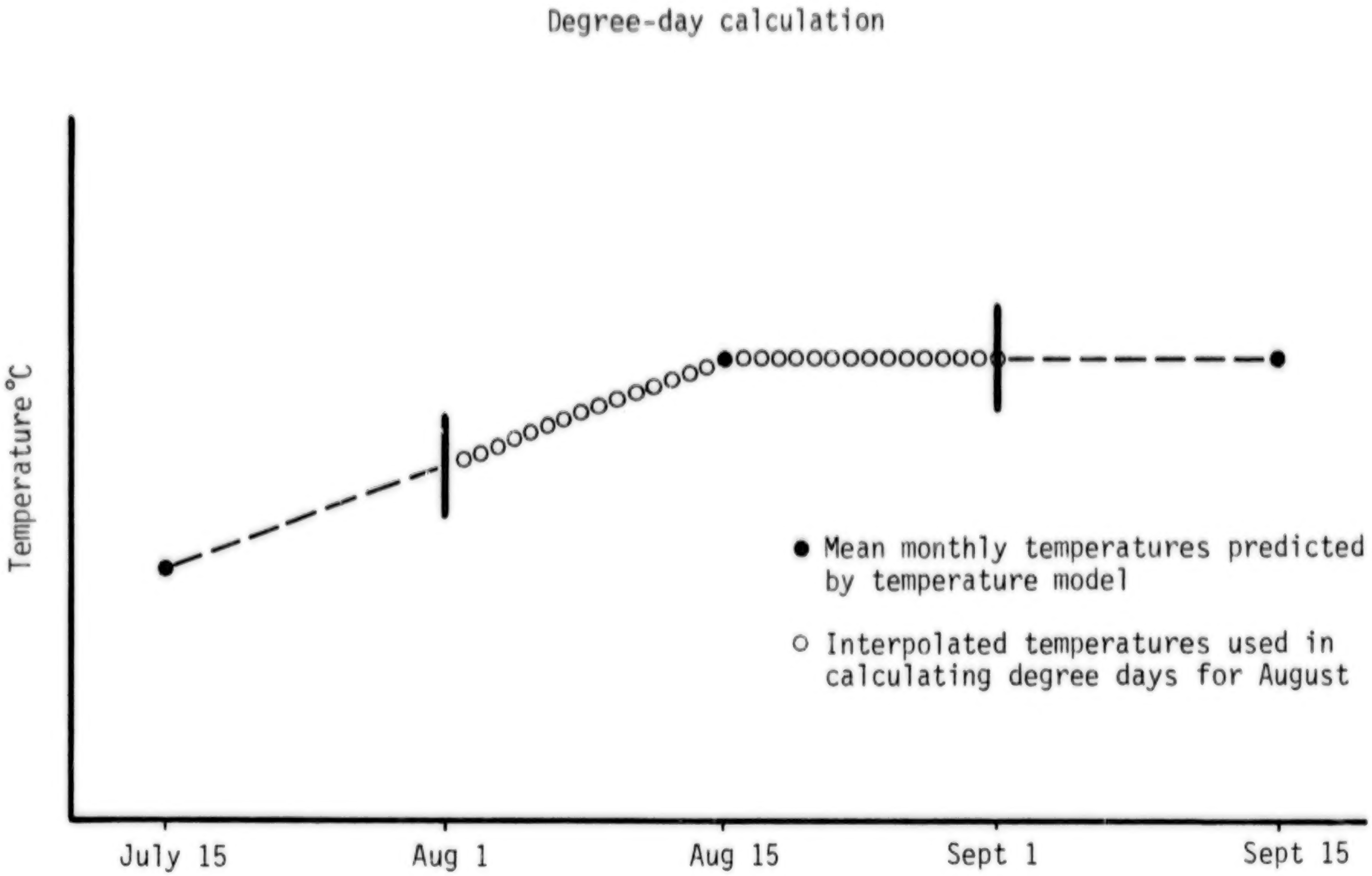


Figure 5. Illustration of how degree-days are simulated from monthly temperatures.

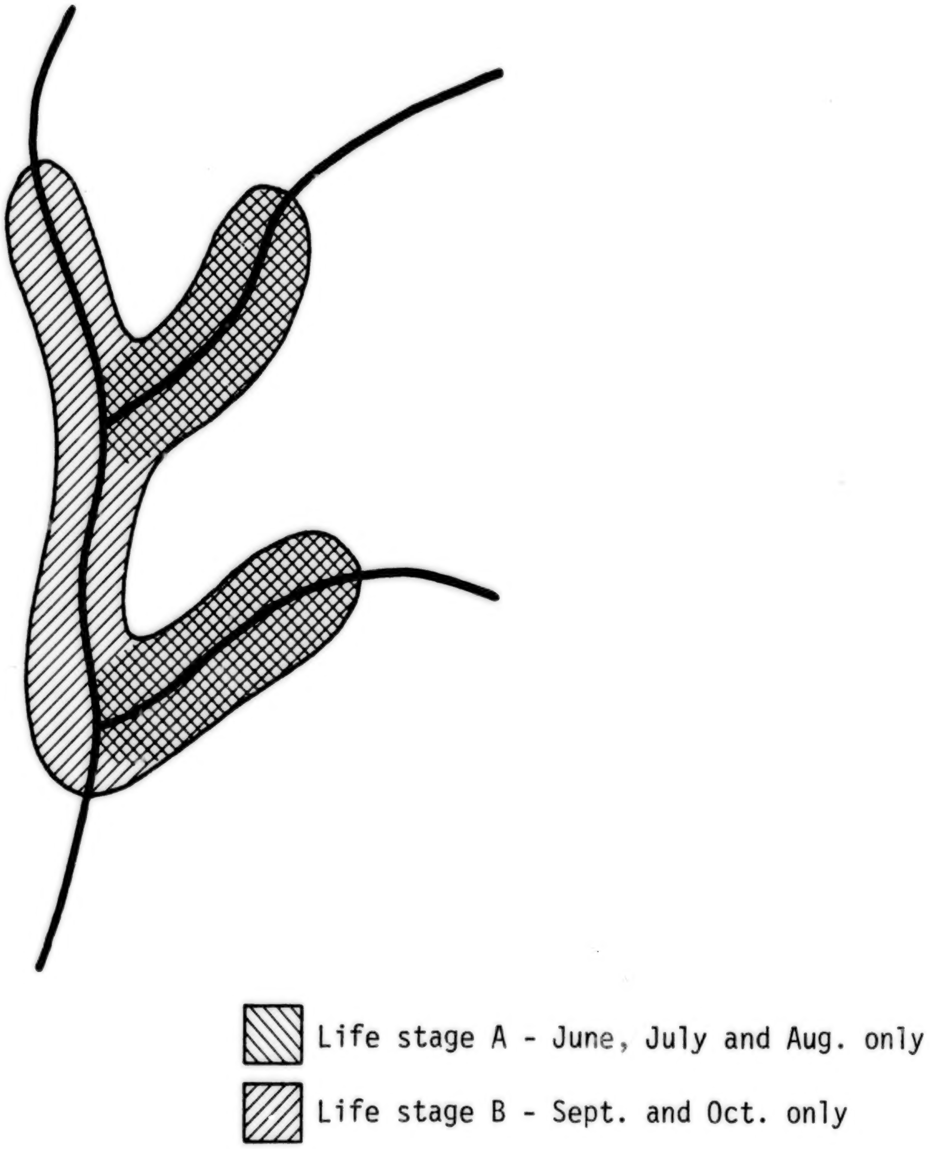
The degree-days are calculated from the interpolated temperatures for each day. Temperatures are constrained within user-specified bounds (see input options section) and checked to see if the degree-days counter needs to be reset. This reset option is provided to allow for aquatic species that might have a threshold, below or above which accumulated degree-days essentially must start over. The user also controls the number of consecutive days necessary to cause a reset condition. Degree-days may be cumulatively added or they may be tabulated only for each independent time step. Finally, each day's contribution of degree-days is summed for the time step.

After one year's calculations are made, the monthly results are written to the time series file. Then the rest of the selected years are processed. The routine then proceeds to the next desired node, if any.

2.1.7 Step seven calculates the usable area for each life stage through time and space. At each node, the routine determines which months are applicable (Figure 6). Applicability of each month is determined both from the job control file and the habitat vs. flow data file. Both month indicators must be "on" to be applicable. If applicable, the flow is determined and the corresponding Weighted Usable Area (in sq. ft. per 1000 ft.) is interpolated from the habitat-flow relationship. If the flow is less than the lowest flow in the curve, or greater than the highest flow, a message is printed and the WUA is set to zero.

Next, the biological reach is sampled at the user-defined distance (in kilometers), and the temperatures at the head and tail of every subsection are averaged (Figure 7) and then modified by the Temperature Adjustment Factor. The corresponding SI value is interpolated from the SI curve. Again, if the predicted temperature falls below the lowest point in the SI curve or above the highest point, a message is printed and the SI value is set to zero. The SI value is multiplied times the WUA and the subsection length to give square feet of habitat. If no SI curve data are supplied for this life stage, the reach is not sampled for temperatures. Instead, the SI value is assumed to be 1.0, and thus the WUA is multiplied by the reach length to give square feet. The square feet are summed for each subsection until the entire biological reach is covered. Note that the reach length is supplied in miles and the temperature sample distance in kilometers.

This process repeats for all applicable nodes. Any node for which there is no flow-WUA curve for a life stage is ignored. The total area for all nodes for each life stage are added together to complete the networkwide approach. Finally, each year's worth of data is written to the Habitat Time Series data file (L3HTS). Inapplicable months are assigned a value of



Total system habitat

▧ Life stage A - June, July and Aug. only
▨ Life stage B - Sept. and Oct. only

Figure 6. Illustration of how different life stages use different reaches during different times of the year.

Temperature gradient through reach

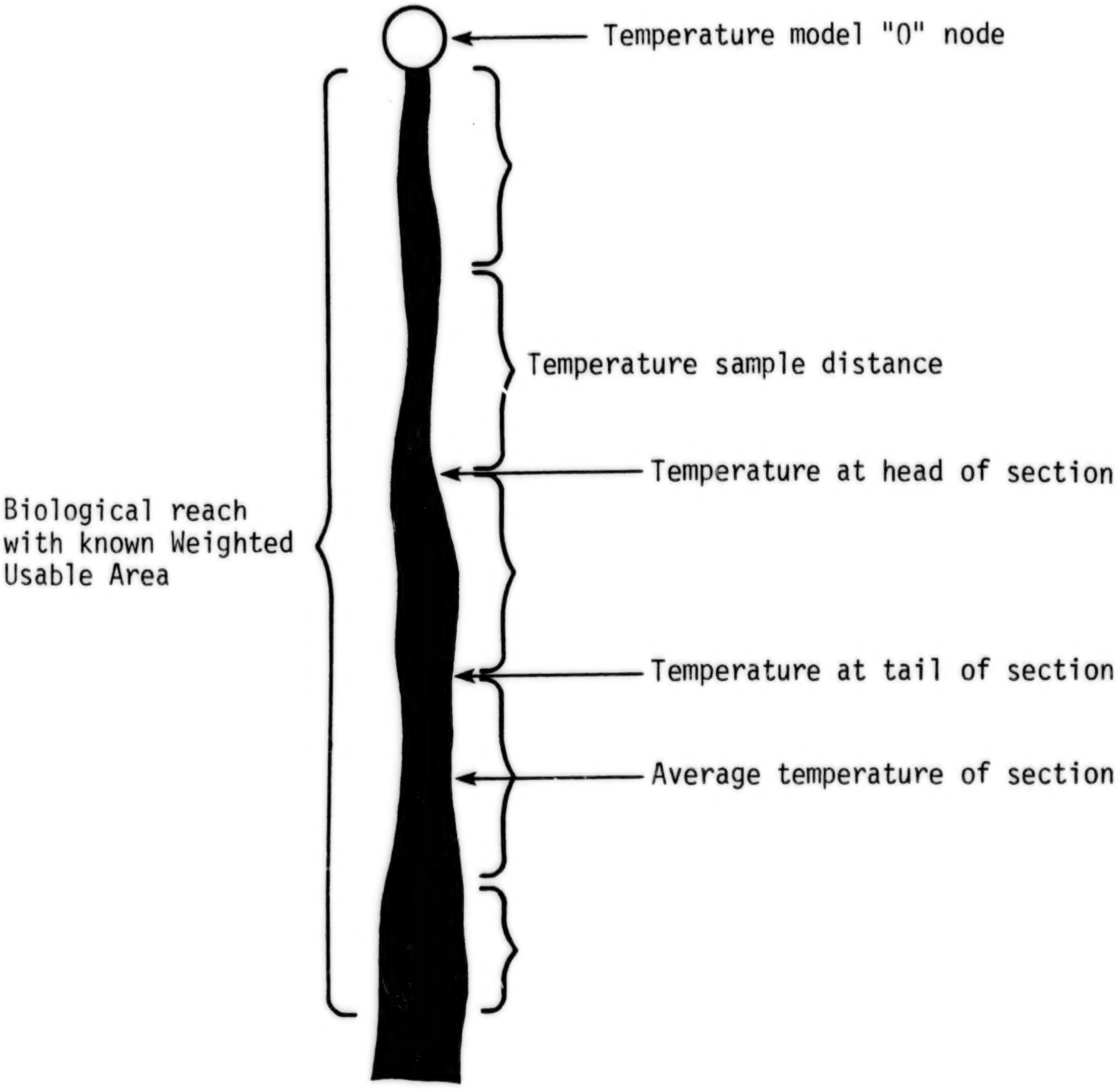

Temperature model "0" node
Temperature sample distance
Temperature at head of section
Biological reach with known Weighted Usable Area
Temperature at tail of section
Average temperature of section

Figure 7. Illustration of how temperatures are calculated and used throughout a biological reach.

1.E-99 to be distinguished from zero. Note that if a life stage is found at one node during October, but not at another node in that same month, only applicable node/month combinations will be summed.

It is worth mentioning that it is illegal to try to predict temperatures downstream from "B", "T", or "E" nodes. Further, this program does not recognize node boundaries when sampling throughout the biological reach. For example, suppose one node was at kilometer 100 and a second was at kilometer 75. Suppose that you entered a flow-WUA curve for life stage X at node 100 and said the biological reach length was 50 kilometers. (However, recall that you specify this in miles.) This routine will sample water temperatures from kilometers 100 to 50 using parameters from the node at 100 and ignore any changes that really should occur. It is the user's responsibility to further subdivide reaches if necessary.

If the flow goes to zero, the routines will predict a water temperature that is the same as the air temperature under the presumption that the depth goes to zero.

2.2 Options

The primary options for this program are controlled by the job control data file (L3JCF) (Figure 4). Through the proper use of this file, you may control which nodes to aggregate, which life stages to work with, and what time period, both in years and months, is to be covered. In this way, comparisons may easily be made across both time and space for any biological requirement.

Degree-day options are provided primarily in the job control file. The most relevant options are schematically depicted here:

```
T  |  \                  /
E  |---\-----------------/----------- Upper Bound
M  |    \               /
P  |-----\-------------/------------- Upper Reset
E  |      \           /
R  |-------\---------/--------------- Benchmark
A  |        \       /
T  |---------\-----/----------------- Lower Reset
U  |          \   /
R  |-----------\-/------------------- Lower Bound
E  |            \/
   -------------------------------------------------------
                       TIME ---->>
```

2.2.1 Benchmark - The temperature (Celsius) that is the arbitrary reference for degree-day calculation. Thus, if the benchmark is 12 degrees, a temperature of 15.5 degrees for one day would count as 3.5 degree days. The reference is also specified as MAXimum, AVGerage, or MINimum. That is, you tell the program which daily temperature to compare with the benchmark. Finally, you may also specify an adjustment (fudge factor) to be added or subtracted from the calculated temperature should you need to for some reason. Such an adjustment may prove useful in accounting for some global or basinwide situation, such as backwaters or canyons. The default benchmark is 12 degrees, default reference is AVG, and default adjustment is zero.

2.2.2 Bounds - Upper and lower bounds are entered for daily temperatures. If, for example, only positive degree-days are desired, you should set the lower bound equal to the benchmark. Thus, if the benchmark were 12 degrees and the daily temperature were 10 degrees, the 10 degrees would be reset to 12 degrees for an accumulation of 0 degree-days. Similarly, if there is a maximum number of degree-days allowed, one may use the upper bound to control accumulation. Thus, if daily temperatures are not biologically "helpful" beyond 28 degrees, set the upper bound to 28. Normally, a 30-degree day would count as 18 (30-12) degree-days. But if the upper bound is 28 degrees, the maximum allowed would be 16 (28-12).

No checks are made on the validity of the bounds with respect to the resets (see below). This will allow maximum flexibility for unforeseen applications. The upper bound, however, must be greater than the lower bound. The default upper bound temperature is 99, and the default lower bound temperature is -99.

2.3.3 Resets - Upper and lower resets are entered for degree-day accumulation. Suppose you are interested in egg maturation. If eggs were resorbed when the daily temperature falls below 5 degrees, you would want to reset the accumulation of degree-days, i.e., start the counter at zero again. You may also specify how many contiguous days are necessary to cause a reset of the accumulation. For example, one day of low temperatures may not cause eggs to be resorbed; perhaps it takes 5 days at or below 5 degrees.

No checks are made on the validity of the resets with respect to the bounds (see above). This will allow maximum flexibility for unforeseen applications. The upper reset, however, must be greater than the lower reset. The default upper reset temperature is 99, and the lower reset temperature is -99.

Suppose, for example, that egg maturation depended on temperatures accumulating degree-days in the range of 12 to 20 degrees. Temperatures above 20 would not count any more than 8 degree days. Also, if temperatures reached 32 degrees, the eggs would be killed and a new set must begin to mature. In this case, the upper bound should be 20 and the upper reset should be 32.

Note that there is also an automatic reset if one or more months are not being processed.

2.2.4 Days per Step - This routine is between general and specific in relation to time (see section on assumptions). Although there must be 12 time steps per year, the time steps need not be months. Even if they are months, data input may vary by water year or calendar year. In any event, you must supply the number of days per time step for proper interpolation to occur. It is recommended that you supply 30 days for 30-day months, 28 days for February, and 31 days for the other months. The default is 30 days. The default number of days to reset is zero.

2.2.5 Counting Method - Degree-days may be tabulated time step by time step or cumulatively. If, for example, you desire the time series data file to contain the number of degree-days for each month, use the "INDEPENDEN"t option. If you want the degree-days to accumulate from the last reset, use the "CUMULATIVE" option. To be meaningful, the cumulative option should be used only with the reset option. The handiest way to reset is to not run one or more months of the linkage.

In addition to INDEPENDENT and CUMULATIVE, there is an ICOUNT and CCOUNT option.

Unlike a true degree-day calculation, ICOUNT and CCOUNT serve only to tabulate the number of consecutive days on which the temperature exceeds the specified benchmark. As before, the benchmark is specified as MIN, AVG, or MAX with its associated bias. Upper and lower bounds and resets operate as before.

For example, suppose the benchmark has been specified as 20 degrees Celsius average daily temperature. If you request the ICOUNT option, the number of consecutive days in each month that are 20 degrees or higher will appear in the time series output. If you choose the CCOUNT option, the time series output will show the month-to-month accumulation. In other words, ICOUNT is parallel with INDEPENDENT and CCOUNT is parallel with CUMULATIVE.

2.2.6 Normals Year - Typically, data from the temperature model will contain one or more years of synthetic data, such as normals. Normals, as used here, means average monthly values for a specified number of years. For proper and less expensive interpolation for degree-days, you should specify which "year" is to be used for normals. If your data set runs from 1960 to 1982 with 1 year of synthetic normals, those normals are stored as if they were year 1983 data. Thus, you would specify 1983 as your normals year.

You must specify a normals year if your time periods are other than months. If you do not, the "wrap-around" method of calculating normals that the program uses will be incorrect. For example, normals for the time step prior to one are assumed to come from time step 12. This is fine if the time steps are months, but not otherwise. The default is zero, which means that normals are to be calculated by the program.

Should you wish to calculate degree-days for the "normals" year, and do so 100% accurately, you should run the normals year alone so that no previous year's data will be mingled with time step one.

2.2.7 The Temperature Sample Distance (kilometers) controls how temperature is sampled throughout a biological site. The biological reach will be sampled at the specified sample distance to determine the temperature at the head of each subsection and the tail. These head and tail temperatures will be averaged and the temperature SI value will be interpolated from the SI curve to determine the multiplier for the weighted usable area for that subsection. The flow will always be the same, but the temperature will gradually change. For practical purposes, sample distances less than about 10 kilometers probably will not lead to improved results.

NOTE: It is somewhat confusing to have a different set of units here. I tried to keep all PHABSIM units in English and all temperature model-related units in International Units. But this can get confusing and calls for care. The program prints out its assumptions about units as it goes along. You should check the MESSGS file carefully to make sure it agrees with your expectations.

Other options are effectively provided with the other data input files. For example, weights may be applied to each life stage at each node representing the river reach length and/or relative priority to be assigned to the habitat value at that location.

2.3 Input Files Description

2.3.1 L3JCF -- Job Control File, formatted

The job control file may be used to control the overall execution of this program. An example of the job control file is shown in Figure 4.

The title that ends up on the habitat time series file (L3HTS) is the first title line in the job control file.

The first year of data requested (79 in the example) refers to the calendar or water year from the temperature model output file (KTRNSPT). The number following the first year is the bias for the starting year of the temperature model. Unfortunately, the KTRNSPT file does not contain the data needed to tell which years are what. Thus, in this case we must tell the linkage that KTRNSPT begins in year 59. NOTE that all years should be truncated to the last two digits. Thus, 1972 becomes 72.

The last year (82) refers to the last year of temperature model output you want processed.

The 12 time period flags almost always will refer to the months of temperature model output. If 1, that month will be processed; if 0, that month will be skipped. A 0 month will also reset the degree-day counter if a reset option is in place. The months will always be in the order specified by the units, calendar year, or water year.

The nodes list and the species/life stage list may contain any number of descriptions. A "T" is used in column one to indicate which are to be used in processing. An "F" is used in column one to indicate that which should not be processed. Columns 2 thru 80 contain the node identifier or species/life stage.

The following is the format used for each line of the nodes list:

Column	Format	Description
1	A1	Processing indicator: T = process this node F = do not process this node
2	1X	Blank
Node Identifier:		
3-18	16 Char	Stream name
19-26	8 Char	Node type
27-34	F8.1	Stream distance
35-80	46 Char	Stream location remark Note: this remark is 2 characters shorter than normal-ensure that uniqueness was not previously established by the last 2 characters. This list must be followed by an end-of-list indicator:
1-10	A10	10 asterisks

Note: At least one node must be processed. This program will stop with a fatal error if there are no nodes.

The following is the format used for each line of the species/life stages list:

Column	Format	Description
1	A1	Processing indicator: T = process this species/life stage F = do not process this species/life stage
2	1X	Blank
3-12	10 Char	Species name (left justified)
13-22	10 Char	Life/stage name (left justified)
		This list must be followed by an end-of-list indicator:
1-10	A10	10 asterisks

Note: This program may be run without a species/life stages list but the end-of-list indicator is still required.

The degree-day switches have all been discussed under the major options section previously.

Notice that the first 10 characters of line 2 contain the units information that will be in the habitat time series output. LNKT2H assumes that the flow data file from the temperature model is in cubic meters per second. If this should change for any reason, the program would need to be modified. In fact, it should be modified at some point to recognize the units and account for them in a general sense. The year type (calendar or water) makes no difference to LNKT2H. To get in the habit of using proper units, please follow the format given below. If you do not, a warning message will be printed.

Time codes which are in cols 1 to 3 (with a trailing :):

1 AY: = agricultural year
2 CY: = calendar year
3 WY: = water year
4 IY: = irregular year
5 = blank

Scale factors which may be in column 4:

1 none = 1.0
2 K = 1×10^3
3 M = 1×10^6
4 G = 1×10^9

Measurement units codes in cols 5-10 (left-justified):
1 ACRES = acres
2 AF = acre feet
3 CFS = cubic feet per second
4 CMS = cubic meters per second
5 DAM3 = cubic decimeters
6 GPD = gallons per day
7 HECTS = hectares
8 IRREG = irregular
9 LPD = liters per day
10 SQFT = square feet
11 SQFT/K = square feet per 1000 feet
12 SQM = square meters
13 SQM/K = square meters per 1000 meters
14 WH = watt hours
15 $ = dollars
16 = blank
17 FT = feet
18 M = meters
19 MI = miles

2.3.2 L3QA - Habitat vs. Flow Data file, formatted

This file contains one species/life stage per record with records separated by at least 10 asterisks (**********). Record, as used here, means life stage, not a single card image and not a CDC record.

For each record:

Line 1 is a title line. This line may need to be deleted for some other PHABSIM applications such as PLTTP8.

Line 2 will be the node identifier. This will correspond to a temperature model node in format. In fact, it will have to match exactly nodes read from the KTRNSPT.

Lines 3 and 4 will be title lines, skipped for this program, but handy to keep track of your data. Again, other PHABSIM applications may require that these titles be deleted.

Line 5 is the species line:

Column	Format	Description
1 -10	A	Species Name
11-29	blank	
31-41	A	12 monthly flags, 1 if month applicable, 0 if not. These values are necessary at all nodes; the month's order depends on whether it is a water year or calendar year.

45-54	F10.0	Habitat threshold--that value (in thousands of square feet), below which a warning error will be printed if the population's usable area falls below it in any month.
55-64	F10.0	Downstream distance, measured in units of miles, is the multiplier for the WUA. The downstream distance is the reach length for which one assumes that the PHABSIM hydraulics and preference criteria apply. Note that if one scenario calls for a reservoir that will inundate part or all of a 'biological' reach, you must account for that inundation by adjusting the distance factor. Also, this distance may be adjusted to account for a life stage 'weight'.

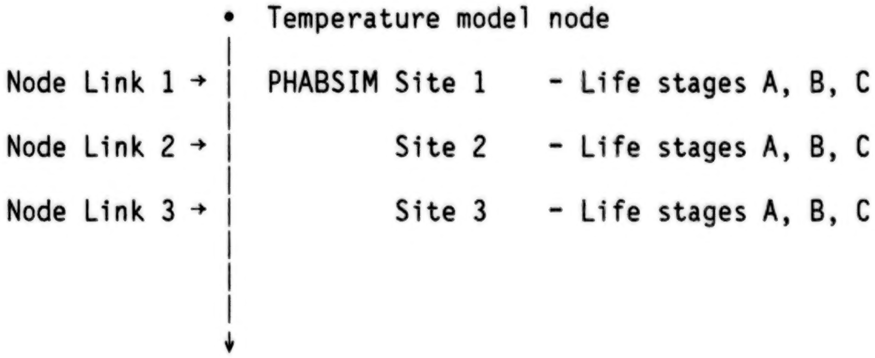
Line 6 is 'DISCHARGE' and life stage data line:

Column	Format	Description
18-27	A	Life Stage Name

Line 7 thru N is the Q and WUA data (3X,2F12.0) followed by Line N+1 which is **********, End Of Logical Record. There may be a true -EOR- in the file at this point. This is optional.

Then the format repeats for each new node/life stage. The time, threshold, and distance are required for each node/life stage because they may differ throughout the network. That is, a life stage at one geographic point may have different time and threshold values than at another geographic point.

Note that there may not be more than one identical life stage referring to a single node. For example, suppose that there are three habitat sites in a single stretch of river.


Temperature model node
Node Link 1 →
PHABSIM Site 1 - Life stages A, B, C
Node Link 2 →
Site 2 - Life stages A, B, C
Node Link 3 →
Site 3 - Life stages A, B, C

If life stages A, B, and C were found at each of them, their respective curves must each refer to different nodes in the temperature model output file (KTRNSPT). In this case, one would need to create new or dummy temperature nodes. It should be a simple task to add additional "O" to the temperature model.

A useful alternative to creating new dummy nodes is to combine the WUA/A data by weighting each site relative to its length to produce a single WUA/A curve. Use the following formula to combine the habitat data:

$$\frac{l_1 w_1 + l_2 w_2 + \ldots l_i w_i + \ldots + l_n w_n}{l_1 + l_2 + \ldots + l_n}$$

where: l_i = length of reach i

w_i = weighted usable area for reach i

n = number of reaches

An example flow - WUA data file is shown in Figure 2.

2.3.3 L3TSI - The temperature suitability index file contains preference curve data for each life stage. The data file is organized with one life stage per "record", with records separated by at least 10 asterisks (**********). Record, as used here, means life stage, not a single card image and not a CDC record. For each record:

Line 1 is a title line, 80 columns, free format

Line 2 contains life stage data:

cols 1-10	species name (left justified)
cols 11-20	life stage name (left justified)
cols 25-28	the word MIN, AVG or MAX
cols 30-35	temperature adjustment factor

Line 3 through N is the temperature and SI data (5X,2F5.0)
Temperature data are assumed to be in Celsius
SI data are assumed to be between 0.0 and 1.0

Line N+1 is the logical end of record (**********)

Then lines 2 to N+1 repeat for each new species/life stage. An example of this data file is shown in Figure 3. Note that a format of F5.0 means that you may either right justify an integer or add a decimal. Supplying the decimal is highly recommended.

The MIN, AVG, or MAX label tells the linkage which monthly temperature to use. The adjustment factor allows the addition of a constant value to the chosen temperature. For example, if the preference data really should indicate maximum temperature, but you felt that the aquatic species could find places in the stream to avoid the maximum temperature by 2 degrees Celsius, you should put MAX in the temperature field and -2.0 in the adjustment factor field.

Note that these temperature data are not in standard PHABSIM FISHFIL data format. I decided that it would be better to have the chosen format for four reasons:

(1) No one now uses the temperature data in FISHFIL.

(2) This format is easier to edit and see what is going on.

(3) There are no restrictions, such as including a zero and a 100 coordinate pair, however, it is still wise to do so.

(4) I could add additional things, such as the fudge factor and which reference (MIN, AVG, or MAX) to use.

2.4 Output Files Description

There are three primary output files: the habitat time series file (L3HTS), the degree-day time series file (L3DDTS), and the job summary (MESSGS).

2.4.1 L3HTS - Time series file is arranged one life stage per record. It may be convenient to pull off one record at a time from this file by using the procedure RGET1 from the PHABSIM PROCFIL or any other source. Example output may be found in Figure 8.

Unlike a "standard" USGS or NWDC time series file, this file's station descriptor says SUM. The reason for this is that the habitat values have been aggregated over a network and no single station identifier is relevant. The title of the habitat time series file comes directly from the job control file (L3JCF). The units also come from the first 10 characters of the job file's second title line, except that they have been divided by 1000--thus the insertion of "K".

The very small numbers, 1.E-99, represent months in which the life stage has no biological habitat value. It is not zero, because zero might look like a realistic value. It was felt that a negative value might bomb out some other PHABSIM programs.

```
SQUAYOY
TEMP. MODEL TO MICRO-HABITAT LINK; TEST OF TEMP SI OPTION; PRE INDEX SWITCH
SQUAWFISH YOY          UNITS = WY:KSQFT         84/08/20. 09.09.49.
 SUM           2 1972   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           2 1972   2 1.E-99 1.E-99  27.57  99.63 172.22 414.02     WY:KSQFT
 SUM           2 1973   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           2 1973   2 1.E-99 1.E-99  27.81 188.57 602.43 605.46     WY:KSQFT
 SUM           2 1974   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           2 1974   2 1.E-99 1.E-99  18.86  55.28 169.39 916.79     WY:KSQFT
 SUM           2 1975   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           2 1975   2 1.E-99 1.E-99  51.25 118.09 374.28 500.27     WY:KSQFT
 SUM           2 1976   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           2 1976   2 1.E-99 1.E-99 170.24 488.81 844.91 844.58     WY:KSQFT
 SUM           2 1977   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           2 1977   2 1.E-99 1.E-99  22.85 107.79 698.10 890.51     WY:KSQFT
 SUM           2 1978   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           2 1978   2 1.E-99 1.E-99  32.56 135.82 788.35 829.20     WY:KSQFT
 SUM           2 1979   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           2 1979   2 1.E-99 1.E-99  43.08 213.86 798.38 846.34     WY:KSQFT
 SUM           2 1980   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           2 1980   2 1.E-99 1.E-99 133.21    .00 656.35 686.43     WY:KSQFT
 SUM           2 1981   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           2 1981   2 1.E-99 1.E-99  36.82  88.39 278.87 392.98     WY:KSQFT
 SUM           2 1982   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           2 1982   2 1.E-99 1.E-99  43.27 122.93 636.33 785.80     WY:KSQFT
SQUADEP
TEMP. MODEL TO MICRO-HABITAT LINK; TEST OF TEMP SI OPTION; PRE INDEX SWITCH
SQUAWFISH DEP/FERT     UNITS = WY:KSQFT         84/08/20. 09.09.50.
 SUM           3 1972   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           3 1972   2 1.E-99 1.E-99   3.09  20.69  27.58 1.E-99     WY:KSQFT
 SUM           3 1973   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           3 1973   2 1.E-99 1.E-99   2.31  22.08  26.85 1.E-99     WY:KSQFT
 SUM           3 1974   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           3 1974   2 1.E-99 1.E-99   1.19  23.69  25.87 1.E-99     WY:KSQFT
 SUM           3 1975   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           3 1975   2 1.E-99 1.E-99   6.10  20.62  26.88 1.E-99     WY:KSQFT
 SUM           3 1976   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           3 1976   2 1.E-99 1.E-99  17.56  21.64  12.75 1.E-99     WY:KSQFT
 SUM           3 1977   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           3 1977   2 1.E-99 1.E-99    .08  20.15  25.99 1.E-99     WY:KSQFT
 SUM           3 1978   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           3 1978   2 1.E-99 1.E-99   2.25  21.31  24.25 1.E-99     WY:KSQFT
 SUM           3 1979   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           3 1979   2 1.E-99 1.E-99   3.00  22.68  24.43 1.E-99     WY:KSQFT
 SUM           3 1980   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           3 1980   2 1.E-99 1.E-99  10.78    .00  19.36 1.E-99     WY:KSQFT
 SUM           3 1981   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           3 1981   2 1.E-99 1.E-99    .81  22.85  22.34 1.E-99     WY:KSQFT
 SUM           3 1982   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM           3 1982   2 1.E-99 1.E-99   2.95  21.96  27.06 1.E-99     WY:KSQFT
```

Figure 8. Example Habitat Time Series File (L3HTS).

2.4.2 L3DDTS - The time series file for degree-days is arranged one node per record. It may be convenient to pull off one record at a time from this file by using the procedure RGET1 from PHABSIM's PROCFIL to use in further analysis. Default time series file arrangement is USGS, although NWDC may be selected in the Job Control File. An example degree-day time series file is shown in Figure 9.

The site name (and record title) is not a gaging station number, but a seven-character identifier composed of the first four characters of the river name and three characters depicting the node distance exactly as you would find in the temperature model's hydrology node file.

The units specified in the time series file will incorporate the type of year specified in the job control file but will have measurement units that are IRREGular. This is because degree-days have so many options (different bounds, resets, cumulative or independent, benchmarks, etc.) that there is no suitable standard for units.

2.4.3 MESSGS - Job summary output file

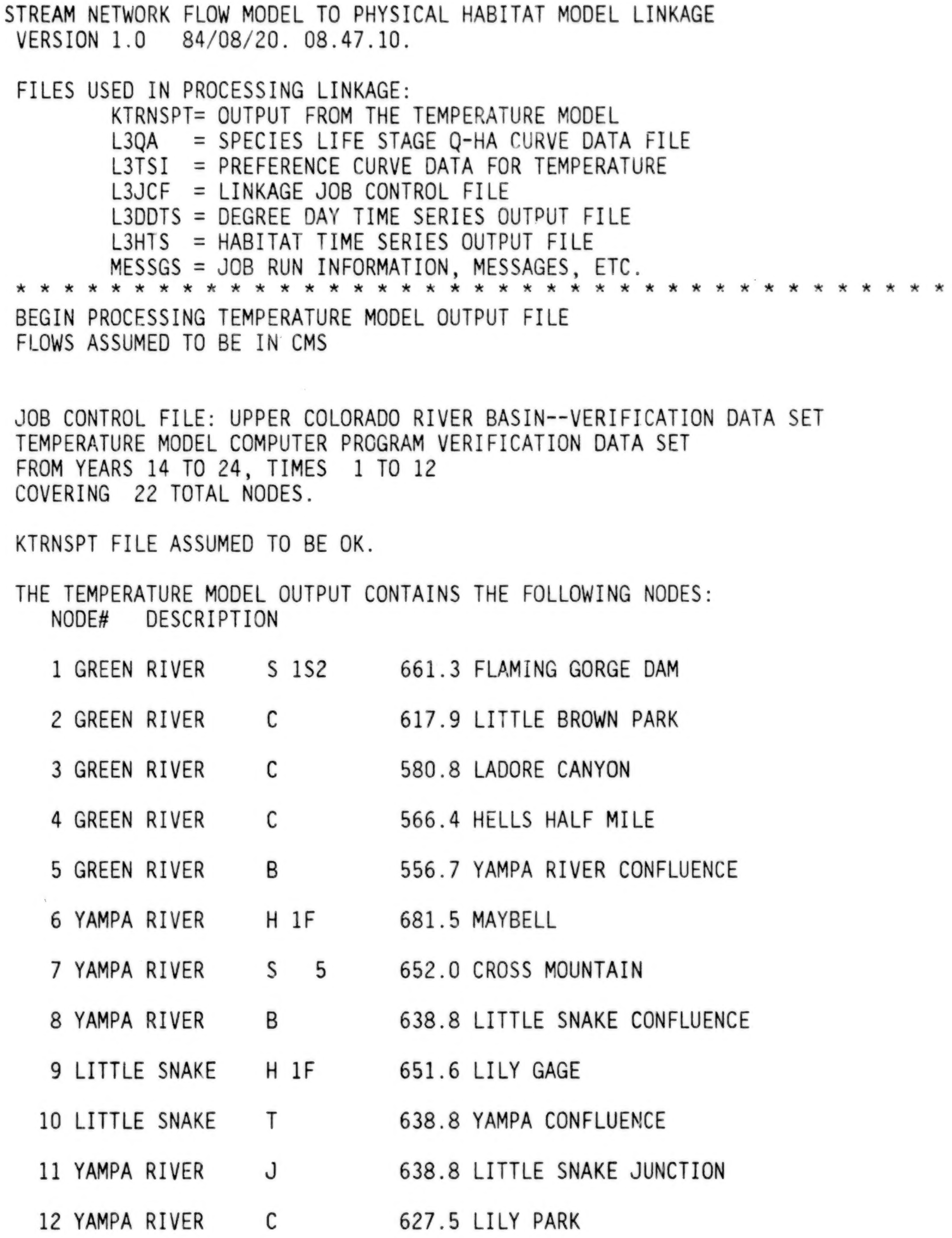
MESSGS contains a complete description of how the job runs, the sequence of events, warning and error messages, and the summary report containing life stage statistics. You should study this output file carefully because it will be an immense help in making sure that you have set up your data files correctly. It will also be invaluable as a record of what you did to accomplish a certain option, along with the date and time of the run. An example of MESSGS may be found in Figure 10.

Past the run summary, the REPORT section should be of particular significance. This section lists for each species/life stage:

1. Life stage name
2. Minimum area encountered
3. When minimum occurred (if more than one time, only first one is reported)
4. Average area encountered
5. Maximum area encountered
6. When maximum encountered (if more than one time, only first one is reported)
7. Percentage of total area contributed by each node

```
YAMP585      84/08/20. 08.47.11.
TEMP. MODEL TO MICRO-HABITAT LINK; TEST OF TEMP SI OPTION; PRE INDEX SWITCH
YAMPA RIVER     C           585.7 HARDING HOLE
 YAMP585        13 1972   1      0      0      0      0      0      0     WY:IRREG
 YAMP585        13 1972   2     10     74    194    277    228    107     WY:IRREG
 YAMP585        13 1973   1      0      0      0      0      0      0     WY:IRREG
 YAMP585        13 1973   2      1     60    189    270    217      0     WY:IRREG
 YAMP585        13 1974   1      0      0      0      0      0      0     WY:IRREG
 YAMP585        13 1974   2      9     68    164    234    214      0     WY:IRREG
 YAMP585        13 1975   1      0      0      0      0      0      0     WY:IRREG
 YAMP585        13 1975   2     12     88    212    302    254    110     WY:IRREG
 YAMP585        13 1976   1      0      0      0      0      0      0     WY:IRREG
 YAMP585        13 1976   2     31    133    233    264    196      0     WY:IRREG
 YAMP585        13 1977   1      0      0      0      0      0      0     WY:IRREG
 YAMP585        13 1977   2      1     51    151    227    201      0     WY:IRREG
 YAMP585        13 1978   1      0      0      0      0      0      0     WY:IRREG
 YAMP585        13 1978   2      0     58    169    239    202      0     WY:IRREG
 YAMP585        13 1979   1      0      0      0      0      0      0     WY:IRREG
 YAMP585        13 1979   2      2     62    184    267    212      0     WY:IRREG
 YAMP585        13 1980   1      0      0      0      0      0      0     WY:IRREG
 YAMP585        13 1980   2     21    108    294    386    263      0     WY:IRREG
 YAMP585        13 1981   1      0      0      0      0      0      0     WY:IRREG
 YAMP585        13 1981   2      1     54    164    273    256      0     WY:IRREG
 YAMP585        13 1982   1      0      0      0      0      0      0     WY:IRREG
 YAMP585        13 1982   2      4     66    185    264    214      0     WY:IRREG
GREE423         84/08/20. 08.47.14. TEMP. MODEL TO MICRO-HABITAT LINK; TEST OF
TEMP SI OPTION; PRE INDEX SWITCH GREEN RIVER      O           423.2 OURAY REFUGE
STUDY SITE
 GREE423        21 1972   1      0      0      0      0      0      0     WY:IRREG
 GREE423        21 1972   2     23     99    195    241    185     85     WY:IRREG
 GREE423        21 1973   1      0      0      0      0      0      0     WY:IRREG
 GREE423        21 1973   2      5     72    207    276    200      0     WY:IRREG
 GREE423        21 1974   1      0      0      0      0      0      0     WY:IRREG
 GREE423        21 1974   2     35    104    168    212    191      0     WY:IRREG
 GREE423        21 1975   1      0      0      0      0      0      0     WY:IRREG
 GREE423        21 1975   2     19    104    210    270    219     93     WY:IRREG
 GREE423        21 1976   1      0      0      0      0      0      0     WY:IRREG
 GREE423        21 1976   2     28    128    228    255    192      0     WY:IRREG
 GREE423        21 1977   1      0      0      0      0      0      0     WY:IRREG
 GREE423        21 1977   2     23     95    182    243    210      0     WY:IRREG
 GREE423        21 1978   1      0      0      0      0      0      0     WY:IRREG
 GREE423        21 1978   2     18     95    193    251    214     97     WY:IRREG
 GREE423        21 1979   1      0      0      0      0      0      0     WY:IRREG
 GREE423        21 1979   2     20    101    216    284    220      0     WY:IRREG
 GREE423        21 1980   1      0      0      0      0      0      8     WY:IRREG
 GREE423        21 1980   2     56    163    333    405    267      0     WY:IRREG
 GREE423        21 1981   1      0      0      0      0      0      0     WY:IRREG
 GREE423        21 1981   2     20     98    207    301    262      0     WY:IRREG
 GREE423        21 1982   1      0      0      0      0      0      0     WY:IRREG
 GREE423        21 1982   2     21     98    198    260    210      0     WY:IRREG
```

Figure 9. Example degree-day time series output file.



```
STREAM NETWORK FLOW MODEL TO PHYSICAL HABITAT MODEL LINKAGE
 VERSION 1.0   84/08/20. 08.47.10.

 FILES USED IN PROCESSING LINKAGE:
        KTRNSPT= OUTPUT FROM THE TEMPERATURE MODEL
        L3QA   = SPECIES LIFE STAGE Q-HA CURVE DATA FILE
        L3TSI  = PREFERENCE CURVE DATA FOR TEMPERATURE
        L3JCF  = LINKAGE JOB CONTROL FILE
        L3DDTS = DEGREE DAY TIME SERIES OUTPUT FILE
        L3HTS  = HABITAT TIME SERIES OUTPUT FILE
        MESSGS = JOB RUN INFORMATION, MESSAGES, ETC.
 * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 BEGIN PROCESSING TEMPERATURE MODEL OUTPUT FILE
 FLOWS ASSUMED TO BE IN CMS


 JOB CONTROL FILE: UPPER COLORADO RIVER BASIN--VERIFICATION DATA SET
 TEMPERATURE MODEL COMPUTER PROGRAM VERIFICATION DATA SET
 FROM YEARS 14 TO 24, TIMES  1 TO 12
 COVERING  22 TOTAL NODES.

 KTRNSPT FILE ASSUMED TO BE OK.

 THE TEMPERATURE MODEL OUTPUT CONTAINS THE FOLLOWING NODES:
    NODE#   DESCRIPTION

    1 GREEN RIVER     S 1S2      661.3 FLAMING GORGE DAM

    2 GREEN RIVER     C          617.9 LITTLE BROWN PARK

    3 GREEN RIVER     C          580.8 LADORE CANYON

    4 GREEN RIVER     C          566.4 HELLS HALF MILE

    5 GREEN RIVER     B          556.7 YAMPA RIVER CONFLUENCE

    6 YAMPA RIVER     H 1F       681.5 MAYBELL

    7 YAMPA RIVER     S   5      652.0 CROSS MOUNTAIN

    8 YAMPA RIVER     B          638.8 LITTLE SNAKE CONFLUENCE

    9 LITTLE SNAKE    H 1F       651.6 LILY GAGE

   10 LITTLE SNAKE    T          638.8 YAMPA CONFLUENCE

   11 YAMPA RIVER     J          638.8 LITTLE SNAKE JUNCTION

   12 YAMPA RIVER     C          627.5 LILY PARK
```

Figure 10. Example MESSGS report.

```
  13 YAMPA RIVER     C          585.7 HARDING HOLE

  14 YAMPA RIVER     T          556.7 GREEN RIVER CONFLUENCE

  15 GREEN RIVER     J          556.7 YAMPA RIVER JUNCTION

  16 GREEN RIVER     C          537.4 ISLAND PARK

  17 GREEN RIVER     C          526.1 RAINBOW PARK

  19 GREEN RIVER     C          502.0 FLATLAND BELOW SPLIT MOUNTAIN

  20 GREEN RIVER     V 1S       485.9 JENSEN GAGE

  21 GREEN RIVER     O          423.2 OURAY REFUGE STUDY SITE

  22 GREEN RIVER     E          399.0 DUSCHESNE RIVER CONFLUENCE

END OF PROCESSING TEMPERATURE MODEL OUTPUT FILE.

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
CHECKING SPECIES/LIFE STAGE Q-WUA DATA FILE:
NODE#     DESCRIPTION
    LIFE STAGE DATA (MONTHS CORRESPOND TO TEMP. MODEL INPUT)

FLOW/HABITAT FILE FOR LINK3 TEST

------------------------------------------------------------------------------
21 GREEN RIVER     O          423.2 OURAY REFUGE STUDY SITE
   1 SQUAWFISH ADULT      HAS  28 FLOW DATA POINTS
       MONTHS = 111111100001  THRESHOLD =       .00  DISTANCE =      15.00 MI.

------------------------------------------------------------------------------
21 GREEN RIVER     O          423.2 OURAY REFUGE STUDY SITE
   2 SQUAWFISH YOY        HAS  28 FLOW DATA POINTS
       MONTHS = 000000001111  THRESHOLD =       .00  DISTANCE =      15.00 MI.

------------------------------------------------------------------------------
13 YAMPA RIVER     C          585.7 HARDING HOLE
   3 SQUAWFISH DEP/FERT   HAS  23 FLOW DATA POINTS
       MONTHS = 000000001110  THRESHOLD =       .00  DISTANCE =        .19 MI.

------------------------------------------------------------------------------
13 YAMPA RIVER     C          585.7 HARDING HOLE
   4 SQUAWFISH STG/REST   HAS  21 FLOW DATA POINTS
       MONTHS = 000000011110  THRESHOLD =       .00  DISTANCE =        .19 MI.

END OF CHECKING SPECIES/LIFE STAGE Q-WUA DATA FILE
YOU HAVE   4 ENTRIES AND   4 UNIQUE LIFE STAGE(S).
```

Figure 10. (Continued)

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 CHECKING SPECIES/LIFE STAGE TEMPERATURE-SI DATA FILE:
 TEST TEMPERATURE - SUITABILITY INDEX FILE FOR UPPER COLORADO

    2 SQUAWFISH YOY           AVG      .00 DEG
      HAS  7 DATA POINTS.
    1 SQUAWFISH ADULT         AVG      .00 DEG
      HAS  8 DATA POINTS.
    3 SQUAWFISH DEP/FERT      AVG      .00 DEG
      HAS  8 DATA POINTS.
    4 SQUAWFISH STG/REST      AVG      .00 DEG
      HAS  8 DATA POINTS.

 END OF READING SPECIES/LIFE STAGE TEMPERATURE-SI DATA FILE.
 YOU HAVE  4 LIFE STAGES REPRESENTED.

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 PROCESSING YOUR JOB CONTROL FILE:

     TEMP. MODEL TO MICRO-HABITAT LINK; TEST OF TEMP SI OPTION; PRE INDEX SWITCH
     WY: SQFT    WILL DEFINE TOTAL AREA IN NETWORK
      UNITS = WY: SQFT
     FIRST YEAR =   72 BIAS =   59
     LAST YEAR  =   82
     MONTHS = 111111111111 CORRESPONDING TO TEMP MODEL

      1  COLORADO RIVER       H 1F      321.8  CAMEO GAGE
      2  COLORADO RIVER       D         320.2  IRRIGATION DEMAND
      3  COLORADO RIVER       B         286.4  GUNNISON RIVER CONFLUENCE
      5  GUNNISON RIVER       T         286.4  COLORADO RIVER CONFLUENCE
      6  COLORADO RIVER       J         286.4  GUNNISON RIVER JUNCTION
      7  COLORADO RIVER       R         257.4  IRRIGATION RETURN
     10  COLORADO RIVER       V 1S      217.2  STATE LINE GAGE
     12  COLORADO RIVER       E         200.0  TERMINAL POINT
      1  SQUAWFISH STAGING
      2  SQUAWFISH DEPOSITION
      3  SQUAWFISH ADULT
     HABTS DATA FMT =    0
     DD UPPER BOUND =  99.0 CELSIUS
     DD UPPER RESET =  99.0 CELSIUS
     DD BENCH MARK =  12.0     AVG    .00 CELSIUS
     DD LOWER RESET =  12.0 CELSIUS
     DD LOWER BOUND =  12.0 CELSIUS
     DD DAYS PER TIME STEP =   31  30  31  31  29  31  30  31  30  31  31  30
     DD COUNTING METHOD = INDEPENDEN
     DD NORMALS YEAR =   82
     DAYS TO RESET DD =    5
     TEMP SAMPLE DIST =  10.00 KILOMETERS

 END OF PROCESSING JOB CONTROL FILE.
```

Figure 10. (Continued)

```
 * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 BEGINNING TO GENERATE DEGREE DAYS TIME SERIES      84/08/20. 08.47.11.
      NODE#   DESCRIPTION
        13   YAMPA RIVER     C          585.7 HARDING HOLE
           = YAMP585
        21   GREEN RIVER     O          423.2 OURAY REFUGE STUDY SITE
           = GREE423
 DATA IS ON FILE "L3DDTS"

 END OF DEGREE DAYS TIME SERIES GENERATION

 * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 BEGINNING TO GENERATE HABITAT TIME SERIES      84/08/20. 08.47.17.

         1 SQUAWFISH ADULT
              = SQUAADU
         2 SQUAWFISH YOY
              = SQUAYOY
         3 SQUAWFISH DEP/FERT
              = SQUADEP
         4 SQUAWFISH STG/REST
              = SQUASTG

 END OF HABITAT TIME SERIES GENERATION
 DATA IS ON FILE "L3HTS"

 * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
BEGIN THE REPORT SECTION

==============================================================================
    1 SQUAWFISH ADULT
           MINIMUM AREA ENCOUNTERED =        0.
               IN YEAR 1972 MONTH  2
          AVERAGE AREA =       459. KSQFT   PER MONTH
           MAXIMUM AREA ENCOUNTERED =     3064.
               IN YEAR 1981 MONTH 12
  NODE  PERCENT  DESCRIPTION
--------------------------------------------------------------------------------
    21   100     GREEN RIVER     O          423.2 OURAY REFUGE STUDY SITE
         -------
         100%
==============================================================================
    2 SQUAWFISH YOY
           MINIMUM AREA ENCOUNTERED =        0.
               IN YEAR 1980 MONTH 10
          AVERAGE AREA =       363. KSQFT   PER MONTH
           MAXIMUM AREA ENCOUNTERED =      917.
               IN YEAR 1974 MONTH 12
```

Figure 10. (Continued)

```
 NODE  PERCENT  DESCRIPTION
------------------------------------------------------------------------------
   21   100      GREEN RIVER     0          423.2 OURAY REFUGE STUDY SITE
       -------
        100%

============================================================================
   3 SQUAWFISH DEP/FERT
          MINIMUM AREA ENCOUNTERED =         0.
              IN YEAR 1980 MONTH 10
         AVERAGE AREA =       16. KSQFT   PER MONTH
          MAXIMUM AREA ENCOUNTERED =        28.
              IN YEAR 1972 MONTH 11
 NODE  PERCENT  DESCRIPTION
------------------------------------------------------------------------------
   13   100      YAMPA RIVER     C          585.7 HARDING HOLE
       -------
        100%

============================================================================
   4 SQUAWFISH STG/REST
          MINIMUM AREA ENCOUNTERED =         0.
              IN YEAR 1972 MONTH  8
         AVERAGE AREA =       11. KSQFT   PER MONTH
          MAXIMUM AREA ENCOUNTERED =        25.
              IN YEAR 1972 MONTH 11
 NODE  PERCENT  DESCRIPTION
------------------------------------------------------------------------------
   13   100      YAMPA RIVER     C          585.7 HARDING HOLE
       -------
        100%

THAT'S ALL FOLKS -- NORMAL END OF JOB

THERE WERE   0 FATAL ERROR(S) IN THIS LINKRUN
     AND   1 WARNING ERROR(S).
```

Figure 10. (Concluded)

2.5 Defaults

The only default conditions used in LNKT2H pertain to the job control file. If data in that file are out of range, then the defaults are to use the first and last years of temperature model data and use all months. The degree-day options are set to NONE. If there are no nodes in the nodes list or an unexpected end-of-file is reached, the program stops with a fatal error.

The default habitat time series data file (L3HTS) format is USGS.

3.0 RELATED SOFTWARE

3.1 Precursors

There are at least two precursors to running LNKT2H: PHABSIM and the temperature model. Both are well beyond the scope of this documentation. However, there are a few hints to be passed along.

Temperature model. When setting up your temperature model data set you must remember to account for the physical habitat sites in the network description. General guidelines would call for establishing a node wherever there is likely to be a change in flow of greater than 10 percent through a habitat site. In this way, accurate translation of flow to habitat value may be retained.

PHABSIM. Aside from assembling all of the habitat vs. flow data files (known as TAPE8s in PHABSIM) into a single file, there remains at least one important task. The upper and lower bounds of each curve should be examined for their ability to handle the extremes of yearly flows likely to be encountered in a HYDROSS run. LNKT2H does no curve extrapolation as do some other PHABSIM routines. If a flow is encountered outside the bounds of a life stage's curve, the habitat value is set to zero. A warning message is provided, but it is the user's responsibility to provide reasonable extrapolations or accept the consequences. It was felt that this approach was more prudent than extrapolation, because pure mathematical extrapolation is not often hydrologically or biologically acceptable.

3.2 Postcursors

We have made much use of PHABSIM plotting and duration analysis programs to continue the analysis of the results of LNKQ2H. Typically, you would use RGET1 to extract single life stages as records from the habitat time series file (L3HTS) or the degree-day time series file (L3DDTS) to be used as input to programs such as LPTDUR and LPTTSN. In the future, links to the Effective Habitat Time Series programs should be performed in the same way. Integration of degree-days with other habitat-related information is required at later steps in the analysis.

3.3 Alternate Methods

There are no alternatives at this time.

4.0 LIMITATIONS

4.1 Accuracy

LNKT2H contains only one mathematical relationship beyond simple format statement kinds of accuracy limitations. The interpolation to calculate WUA given the flow is strictly linear. All constants to change units have at least four decimal places. Accuracy of degree-day calculations is a function of the temperature model's accuracy, a question beyond the scope of this documentation. However, it is important to note that degree-days is an amplification of predicted temperature. That is, if the difference between reported and simulated temperatures is measurable, that difference will be accumulated each day of the time step. This error can add up significantly. Time-step considerations, of course, are important here, too. It is really impossible to look "within" a time step, although we are approximating temperature changes between time steps by interpolation. Though not strictly fair for attempting to replicate the past, this method should be adequate for evaluating the future scenarios.

The water temperature predictions for maximum and minimums are not as good as for average. Maximum and minimum temperatures depend on calculation of travel time and depend on whether you are downstream from a junction or reservoir. If possible, avoid use of maximum and minimum relationships.

Recall the interpolations for degree-day calculations. Because interpolations for a month are made from the preceeding month through to the next month, months that are not at the extremes of the yearly temperature cycle are well represented. Months that are at the peak of the yearly curve, or at the trough, will not be well captured. For example, Figure 11 shows the yearly temperature curve for a generic node. Since each month is really the average temperature, months where the curve has an inflection never are sampled to have any temperatures on the "other" side of the average. In effect, the peak month will contribute somewhat fewer degree-days than it should; similarly, the month at trough will contribute somewhat more than it should. On an annual basis, there should be no net effect. Note that this problem only occurs with the degree-day calculations, not with the habitat time series. Habitat time series is generated exclusively from the monthly means and is never interpolated to a daily basis.

4.2 Assumptions

LNKT2H assumes that the temperature model flows are in units of cubic meters per second, that stream lengths are in miles, and that the WUA units are square feet per 1000 feet of stream. Beyond these, units-in will always equal units-out; though the print out may refer to constant units.

For degree-days, there are few assumptions in this linkage. Most assumptions arise in the setting up of the criteria and the application of the temperature model. It is assumed that all input units are consistent. Further, it is assumed that the time steps are contiguous. That is, the last time step is assumed to immediately preceed the first time step in the next year.

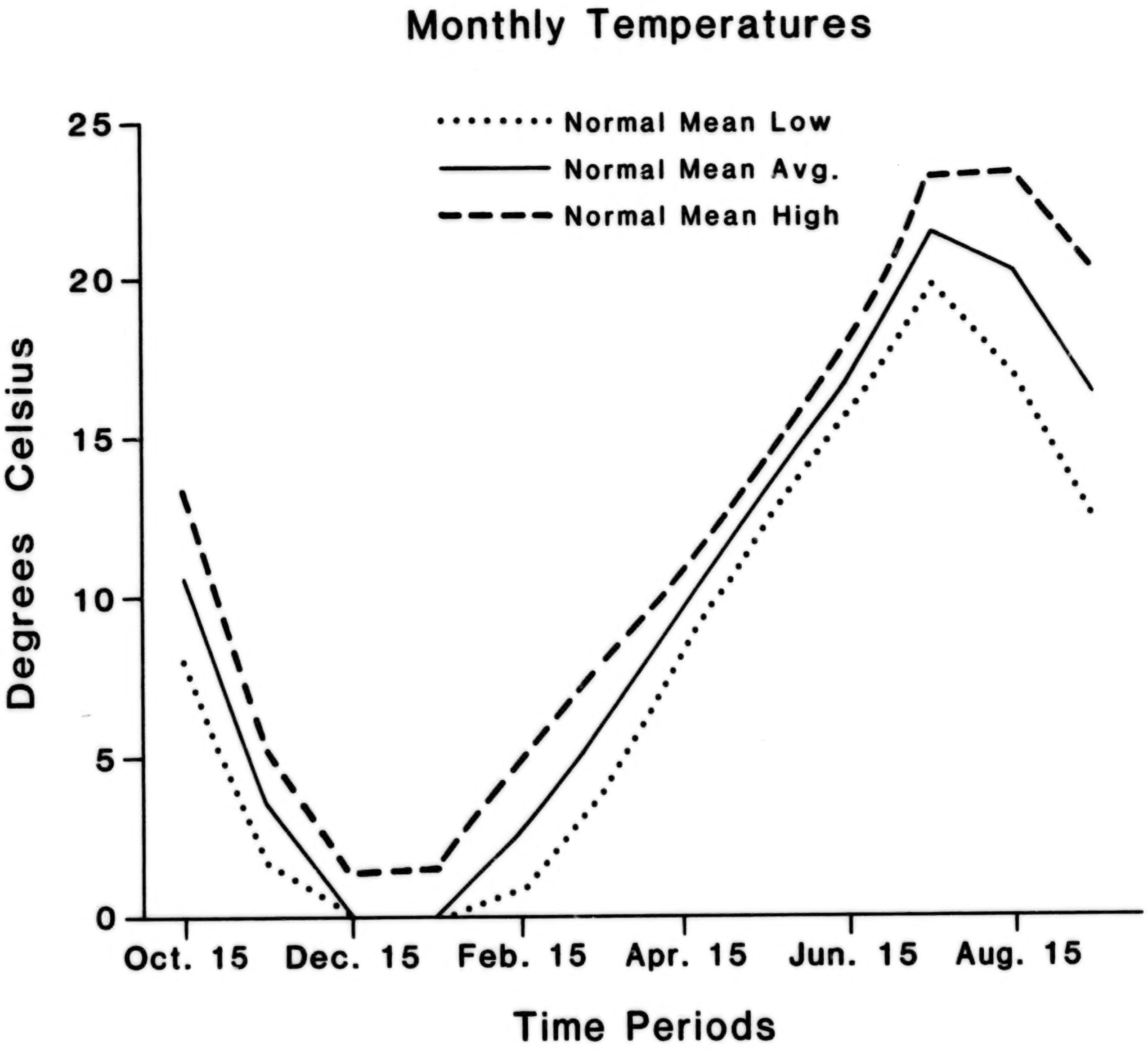


Figure 11. Yearly temperature curve for an example node.

Though calculations are independent of any given time step, the output files do assume monthly format.

If the flow goes to zero, the routines will predict a water temperature that is the same as the air temperature under the assumption that the depth goes to zero.

4.3 Constraints

Current program limits are listed as follows. However, most limits may be changed by altering the parameter statements in the source code and recompiling.

Maximum Number of Nodes	35	
Maximum Number of Life Stages	10	
Maximum Number of Points in HA vs. Q Curve	30	
Maximum Number of years	none	
Maximum Number of Time Steps/Year	12	
Minimum Number of Time Steps/Year	12	- should not be changed
Maximum Number of Points in a T-SI Curve	15	

5.0 MESSAGES

Messages are divided into two categories, warning and fatal. These are listed separately, approximately in the order in which they might be encountered. In general, warning messages will not cause program termination; the job will do its best to continue. Fatal errors, however, will cause either immediate or delayed job termination, depending on the circumstances. The output file (OUTPUT) will provide a run summary for these messages. The messages file (MESSGS) will show the messages in their entirety.

5.1 Warning Messages

a. *** WARNING *** THE NODE ___ WAS ENCOUNTERED IN YOUR Q-WUA DATA FILE, BUT NOT FOUND IN YOUR TEMPERATURE MODEL FILE. PROCESSING SKIPS THIS NODE COMPLETELY.

You may feel free to have a large data base of curves and not refer to them in your linkage.

b. *** WARNING *** BAD SPECIES LIFE STAGE ___ FOUND IN FILE. I WILL TRY TO RECOVER.

Check your curve data file (L3QA) for incorrect number of title lines, no **********, or something like that.

c. *** WARNING *** EXPECTED A NEW LIFE STAGE BUT FOUND AN END OF FILE. I WILL TRY TO CONTINUE.

Check card sequence in curve data file (L3QA).

d. *** WARNING *** TOO MANY UNIQUE LIFE STAGES ENCOUNTERED. I CAN ONLY HANDLE ___. I WILL CONTINUE WITH WHAT I HAVE.

Either remove unessential life stages or recompile program with new parameters.

e. *** WARNING *** TOO MANY POINTS IN CURVE. I ONLY HAVE ROOM FOR ___. I WILL TRY TO RECOVER.

Either remove unessential points or recompile program with new parameters.

f. *** WARNING *** FLOW DATA NOT INCREASING. CHECK DATA FILE FOR flow IN node.

Succeeding flows must increase from record to record to be able to interpolate properly. Check your L3QA data file.

g. *** WARNING *** THIS NODE HAS NO FLOW-WUA DATA POINTS. I WILL TRY TO CONTINUE.

h. *** WARNING *** BAD SPECIES LIFE STAGE FOUND IN FILE. I WILL TRY TO RECOVER.

Check your temperature SI data file for proper syntax.

i. *** WARNING *** LIFE STAGE ____ FOUND IN FILE, BUT IT WAS NOT FOUND IN YOUR Q-WUA FILE. I WILL SKIP THIS RECORD.

This message warns of potential misspellings in life stage name. There is no reason that you must have exact correspondence with life stages among your files, though it makes more sense to keep them parallel.

j. *** WARNING ***

EXPECTED MIN, AVG OR MAX, BUT FOUND ___ INSTEAD.
REFERENCE SET TO AVG.

Check your format in the SI data file.

k. *** WARNING *** TOO MANY POINTS IN CURVE. I ONLY HAVE ROOM FOR ___. I WILL TRY TO RECOVER.

The program has a limit on the number of coordinate pairs that it can remember. If really necessary, you may recompile the program with a new parameter statement.

l. *** WARNING *** TEMPERATURE DATA NOT INCREASING. CHECK DATA FILE FOR ___ IN ___.

Coordinate pairs in SI data file must be in order of increasing temperature. Check your file for the indicated record.

m. *** WARNING *** SI VALUE NOT BETWEEN ZERO AND ONE. CHECK DATA FILE FOR ___. COORDINATES SKIPPED. I WILL TRY TO RECOVER.

By definition, SI data must be between zero and one. If not, the coordinate pair is omitted and processing continues. Check your data file for a missing decimal point or other format error.

n. *** WARNING *** THIS LIFE STAGE HAS NO DATA POINTS. I WILL TRY TO RECOVER.

Probable editing error in SI data file.

o. *** WARNING *** THE FIRST YEAR REQUESTED ___ IS OUT OF BOUNDS OF TEMP.MODEL DATA. I WILL START WITH THE FIRST YEAR OF TEMP. MODEL INSTEAD.

You probably put 1960 instead of 60, for example.

p. *** WARNING *** THE LAST YEAR REQUESTED ___ IS GREATER THAN THE LAST YEAR OF TEMP. MODEL DATA ___. I WILL END WITH THE LAST YEAR OF TEMP. MODEL INSTEAD.

Ditto above.

q. *** WARNING *** YOUR REQUESTED MONTHS WERE BLANK. YOU SHOULD SPECIFY THEM. I WILL PROCEED WITH THEM ALL TURNED ON.

Check the format for the species line in file L3QA.

r. *** WARNING *** THE MAXIMUM NUMBER OF ___ NODES HAS BEEN EXCEEDED. THE FOLLOWING NODE:

____
WILL NOT BE INCLUDED IN PROCESSING.

Processing will continue with the maximum nodes.

s. *** WARNING *** THE FOLLOWING NODE:

____
IS INVALID OR NOT FOUND - IT WILL BE EXCLUDED FROM PROCESSING.

You possibly asked for a nonexistent node. Also check for spelling and/or formatting errors in L3JCF.

t. *** WARNING ***

THE MAXIMUM NUMBER OF ______ LIFE STAGES HAS BEEN EXCEEDED. THE FOLLOWING LIFE STAGE:

____
WILL NOT BE INCLUDED IN PROCESSING.

Processing will continue with the maximum life stages.

u. *** WARNING *** THE FOLLOWING LIFE STAGE:

____

IS INVALID OR NOT FOUND - IT WILL BE EXCLUDED FROM PROCESSING.

You possibly asked for a nonexistent life stage. Also check for spelling and/or formatting errors in L3JCF.

v. *** WARNING *** NO VALID LIFE STAGES WERE FOUND IN L3JCF
PROCESSING WILL CONTINUE WITHOUT LIFE STAGES

w. *** WARNING *** ILLEGAL FORMAT REQUESTED. I WILL DEFAULT TO 0.

Probably a typo or wrong column in L3JCF.

x. *** WARNING *** ILLEGAL BENCHMARK REFERENCE. REFERENCE RESET TO AVG.

Expected MIN, AVG, or MAX in job control file. Check for proper format ___.

y. *** WARNING *** DD LOWER RESET ___ GREATER THAN UPPER RESET ___. LOWER RESET WILL BE SET TO -99.

Check data file.

z. *** WARNING *** DD LOWER BOUND ___ GREATER THAN UPPER BOUND ___. LOWER BOUND WILL BE RESET TO -99.

Check data file for misplaced decimal point or other format error.

aa. *** WARNING *** IN MONTH ___ DAYS PER TIME STEP IS ___. VALUE RESET TO 30.

Missing or negative number of days on data file. Check for problem.

bb. *** WARNING *** DD COUNTING METHOD ___ IS ILLEGAL. RESET TO "NONE".

Expected NONE, CUMULATIVE, INDEPENDENT ICOUNT, or CCOUNT. Check data file for wrong column or other format error.

cc. *** WARNING *** DD NORMALS YEAR ___ IS OUT OF THE BOUNDS OF THE DATA FROM ___ TO ___. NORMALS RESET TO ZERO DEFAULT.

Check for format error in data file.

dd. *** WARNING *** FOUND ___ INSTEAD OF PROPER UNITS.

Consult units tables for legitimate options.

ee. *** WARNING *** FOR life stage AT node, FLOW OF ___ IS BELOW LOWEST FLOW IN Q-HA RELATIONSHIP.

Zero will be used. You should supply interpolation.

ff. *** WARNING *** FOR LIFE STAGE AT NODE, FLOW OF ___ IS GREATER THAN HIGHEST FLOW IN Q-HA CURVE.

Zero will be used. You should supply interpolation.

gg. *** WARNING *** FOR LIFE STAGE ___ AT NODE ___, I CANNOT APPLY TEMPERATURE SI VALUES DUE TO ILLEGAL (B, T, OR E) NODE TYPE.

Program cannot predict temperatures downstream from one of the stated nodes. Use an "O" node instead. Using an O node really doesn't fix the reason why if you think about it, but it does make you think about it!

hh. *** WARNING *** FOR ___ AT ___, TEMPERATURE OF ___ IS BELOW LOWEST POINT IN T-SI CURVE.

Predicted temperature is not within the bound of your SI curve. You must interpolate, not the model.

ii. *** WARNING *** FOR ___ AT ___, TEMPERATURE OF ___ IS ABOVE HIGHEST POINT IN T-SI CURVE.

Predicted temperature is not within the bounds of your SI curve. You must interpolate, not the model.

jj. YEAR = MONTH = ________ FLOW OF _______ PROVIDED AN AREA OF _____. THIS IS BELOW YOUR THRESHOLD OF ______ KSQFT.

This relates to the threshold value on your species line in L3QA data file.

5.2 Fatal messages

a. $$$ FATAL ERROR TEMPERATURE MODEL OUTPUT CONTAINS ___ NODES. I ONLY HAVE ROOM FOR ___. I MUST STOP.

Program limits are being exceeded. You must recompile with a new parameter statement.

b. FATAL ERROR: DID NOT GET SUFFICIENT DATA FROM LIFE STAGE FILE TO CONTINUE WITH PROCESSING.

You must have at least one valid node/life stage with at least 1 data point. Chances are you goofed on this data file (L3QA).

c. $$$ FATAL ERROR: NO VALID NODES WERE FOUND IN L3JCF FILE. PROCESSING CANNOT CONTINUE.

There must be at least one valid node in the L3JCF nodes list in order to execute this program. Check formatting and spelling in L3JCF.

d. $$$ FATAL ERROR $$$ UNEXPECTED END FOUND ON JOB CONTROL FILE. PROCESSING CANNOT CONTINUE.

Check formatting of L3JCF file.

e. $$$ FATAL ERROR: PROBLEM WITH RANDOM FILE IN SUBROUTINE DDTS.

Problem reading temperature model output file (KTRNSPT).

f. $$$ FATAL ERROR: PROBLEM WITH RANDOM FILE IN SUBROUTINE WRITHTS

Problem reading temperature model output file (KTRNSPT).

g. $$$ FATAL ERROR: ODD STRUCTURE FOR TEMPERATURE MODEL OUTPUT FILE.

Problem reading temperature model output file (KTRNSPT).

6.0 TIME/COST

A run for 11 years at 22 temperature nodes may cost $30 the first time.

These estimates, of course, do not include time to set up and debug data files. Though difficult to estimate, please allow up to 2 days to really get started. This ignores setting up and running the temperature model.

7.0 UNUSUAL APPLICATIONS -- None.

8.0 POSSIBLE MODIFICATIONS

The error needs to be fixed and units properly recognized instead of trusted. Also, you could tell when degree-day resets and bounds were reached.

9.0 SUPPLEMENTAL MATERIAL

See also the PHABSIM, HYDROSS, and TEMPERATURE MODEL documentation. Also refer to documentation for LNKQ2T.

10.0 HARDWARE

1. Standard - Any system supporting standard FORTRAN 77.
2. Required peripherals - none.

11.0 ACKNOWLEDGEMENTS

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APPENDIX D

TITLE -- LNKG2H (Gage Data to Habitat Model) Version 1.4

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May 1985

1.0 INTRODUCTION

This program provides a linkage between a monthly flow time series data set model and the Physical Habitat Simulation System (PHABSIM), developed by the Cooperative Instream Flow Service Group, U.S. Fish and Wildlife Service.

This linkage will match the flows provided by the times series data set with the habitat vs. flow relationship data from PHABSIM for one or more life stages at one or more geographic locations. It will then modify that habitat value with temperatures provided from the data set to produce a networkwide habitat time series for each unique life stage. The temperature induced habitat modification is accomplished with the use of a temperature vs. suitability index relationship for each life stage.

Input data are provided by the flow time series and the temperature time series. The primary output is in the form of a U.S. Geological Survey (USGS) or Northwest Data Center (NWDC) monthly time series data file. The time series data may then be used in subsequent time series manipulations such as plots and duration analyses.

This program is more than a linkage, but less than a real stream network habitat model because there remain numerous subjective and objective judgements after the results are obtained. This program is a member of a family of programs in the network habitat analysis family. This group includes:

LNKQ2T - HYDROSS to TEMPERATURE MODEL
LNKT2H - TEMPERATURE to HABITAT MODEL
LNKQ2H - HYDROSS to HABITAT MODEL
LNKG2H - GAGE DATA to HABITAT MODEL (this program)
LNKT2TS - TEMPERATURE TO TIME SERIES PROGRAM

1.1 Execution Procedure

This program *can* be run in BATCH mode.

```
/JOB
SNAB,P2.
/USER
/CHARGE,*.
COMMENT. P2 = DEFAULT
COMMENT. P3 = 6PM TO 6AM
COMMENT. P5 = SAT, SUN & HOLIDAYS
PURGE,QOUT/NA.
DEFINE,QOUT.
COMMENT. JOB CONTROL FILE, TL5BAT, FOR GAGE DATA TO HABITAT
COMMENT. MODEL PROGRAM, LNKG2H.
GET,L4JCF= JOB CONTROL FILE.
GET,L4GAGE= GAGING DATA FILE.
GET,L4TMPR= TEMPERATURE DATA FLE.
GET,L4QA= WUA-FLOW FILE.
GET,L4TSI= PREFERENCE CURVE DATA FILE.
GET,XLNKG2H.
XLNKG2H.
REWIND,*.
COPY,OUTPUT,QOUT.
COPY,MESSGS,QOUT.
COPYSBF,L4HTS,QOUT.
REWIND,QOUT.
COPY,QOUT,QQ.
CSTLOG,QLNK4.
DAYFILE,QA.
REPLACE,QA.
EXIT.
STATUS,F.
REWIND,*.
COPY,OUTPUT,QOUT.
COPY,MESSGS,QOUT.
COPYSBF,L4HTS,QOUT.
COPY,PMDUMP,QOUT.
CSTLOG,QLNK4ER.
DAYFILE,QAA.
REPLACE,QAA.
```

2.0 APPLICATION

2.1 Description of Logic

From a user's perspective, LNKT2H does the following:

2.1.1 Step one opens and rewinds all files necessary for operation (Figure 1).

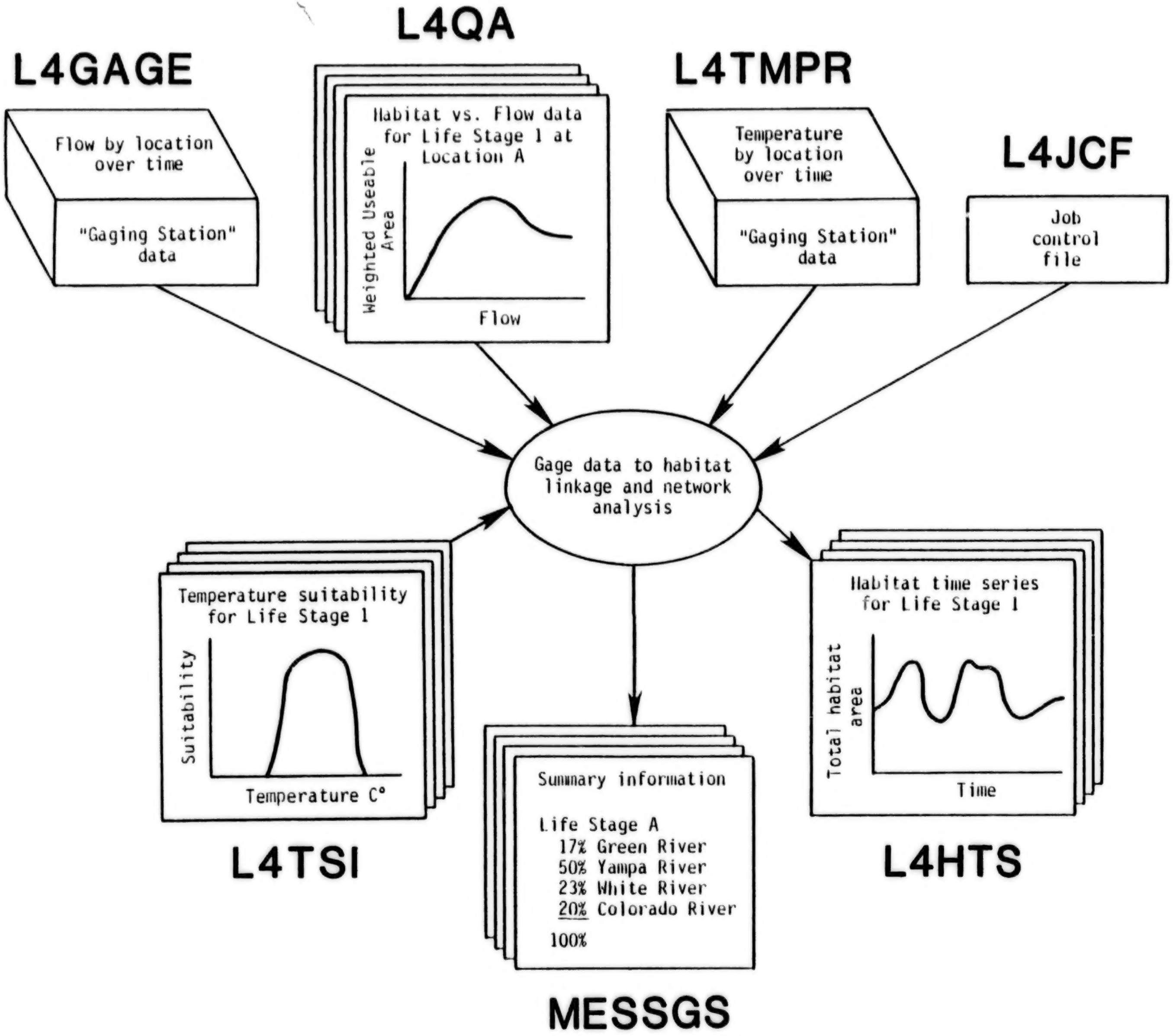


Figure 1. Essential input and output files for the gage data to habitat model linkage.

Input:

- L4GAGE - Flow time series file
- L4TMPR - Temperature time series file (optional)
- L4QA - Habitat vs. Flow data file, must be local
- L4TSI - Temperature Suitability Index (SI) data file (optional)
- L4JCF - Job control file, must be local

Output:

- OUTPUT - For brief program termination messages
- MESSGS - For run status, error messages and summary report. This file is rewound at the end of the run.
- L4HTS - For the habitat time series data. This file is rewound at the end of the run.

2.1.2 Step two reads the gaging data file (L4GAGE). This output file tells LNKG2H how many years exist in the file. Next the routine reads the actual data, which include the gaging station/node names and flow data.

The routine will list to the MESSGS file the node names and their assigned node numbers.

2.1.3 Step three reads the temperature data file (L4TMPR). This file tells LNKG2H how many years of data it contains. Next the actual data are read, including the gaging station/node names and temperature data.

The routine will list to the MESSGS file the node names.

2.1.4 Step four reads the Weighted Usable Area (WUA) Vs. Flow data file (L4QA). This file provides a habitat-flow relationship for each life stage at each geographic location.

2.1.5 Step five reads the Temperature Suitability Index (SI) data file (L4TSI). This routine reads the preference curve data for each species/life stage.

2.1.6 Step six reads the Job Control File (L4JCF). The job file is the primary way to control most options in the program including which years, months, and life stages to use.

2.1.7 Step seven calculates the usable area for each life stage through time and space. At each node, the routine determines which months are applicable (Figure 2). Applicability of each

Total system habitat

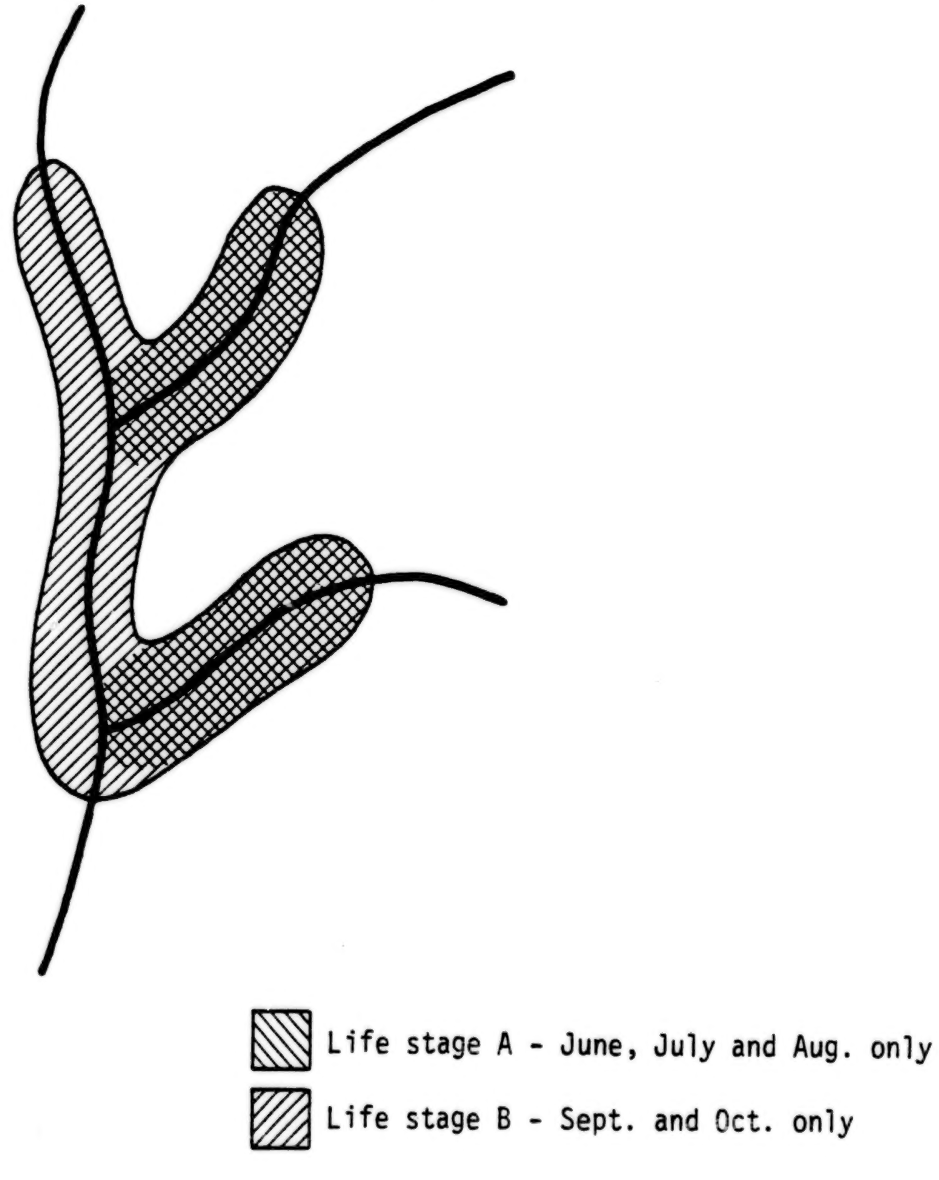

▧ Life stage A - June, July and Aug. only
▨ Life stage B - Sept. and Oct. only

Figure 2. Illustration of how different life stages use different reaches during different times of the year.

month is determined both from the job control file and the habitat vs. flow data file. Both month indicators must be "on" to be applicable. If applicable, the flow is determined and the corresponding Weighted Usable Area (WUA) (in sq. ft. per 1000 ft.) is interpolated from the habitat-flow relationship. If the flow is less than the lowest flow in the curve, or greater than the highest flow, a message is printed and the WUA is set to zero.

Next the corresponding temperature value is retrieved and the SI value is interpolated from the SI curve. Again, if the temperature falls below the lowest point in the SI curve or above the highest point, a message is printed and the SI value is set to zero. The SI value is multiplied times the WUA and the reach length to give square feet of habitat. If there are no SI and temperature data supplied for a particular life stage, then this process does not occur. Instead the WUA is multiplied times the reach length to give square feet. If, however, SI and temperature data have been partially provided for a life stage, then the processing of the life stage is skipped and no time series data are produced. This is to ensure that data will not be produced for one life stage containing both temperature-conditioned and nontemperature-conditioned habitat values.

This process repeats for all applicable nodes. Any node for which there is no flow-WUA curve for a life stage is ignored. The total area for all nodes for each life stage is added together to complete the networkwide approach. Finally, each year's worth of data is written to the habitat time series data file (L4HTS). Inapplicable months are assigned a value of 1.E-99 to be distinguished from zero. Note that if a life stage is found at one node during October, but not at another node in that same month, only applicable node/month combinations will be summed.

2.2 Options

The primary options for this program are controlled by the job control data file (L4JCF). Through the proper use of this file, you may control which nodes to aggregate, which life stages to work with, and what time period, both in years and months, is to be covered. In this way, comparisons may easily be made across both time and space for any biological requirement.

Other options are effectively provided with the other data input files. For example, weights may be applied to each life stage at each node representing the river reach length and/or relative priority to be assigned to the habitat value at that location.

2.3 Input Files Description

2.3.1 L4JCF -- Job Control File, formatted

The job control file may be used to control the overall execution of this program. An example of the job control file is shown in Figure 3.

The title that ends up on the habitat time series file (L4HTS) is the first title line in the job control file.

The first year of data requested (79 in the example) refers to the calendar or water year from the gaging data file (L4GAGE). NOTE that all years should be truncated to the last two digits. Thus, 1972 becomes 72.

The last year (82) refers to the last year of gaging data you want processed.

The 12 time period flags almost always will refer to the months of gaging station data. If 1, that month will be processed; if 0, that month will be skipped. The months will always be in the order specified by the units, calendar year, or water year.

The nodes list and the species/life stage list may contain any number of descriptions. A "T" is used in column one to indicate nodes to be used in processing. An "F" is used in column one to indicate nodes that should not be processed. Columns 2 thru 80 contain the gaging station identifier or the species/life stage.

The following is the format used for each line of the gaging stations/ nodes list:

Column	Format	Description
1	A1	Processing indicator: T = process this node F = do not process this node
2	1X	Blank

Gaging station/node identifiers:

3-18	16 Char	Stream name
19-26	8 Char	Node type
27-34	F8.1	Stream distance
35-80	46 Char	Stream location remark Note: this remark is 2 characters shorter than normal - ensure that uniqueness was not previously established by the last 2 characters This list must be followed by an end-of-list indicator:
1-10	A10	10 asterisks

```
LNKG2H - GAGE DATA TO HABITAT MODEL TEST
WY: SQFT
FIRST YEAR OF DATA   1971
LAST YEAR OF DATA    1980
MONTHS              111111111111
T COLORADO RIVER  H 1F       321.8 CAMEO GAGE
T COLORADO RIVER  D          320.2 IRRIGATION DEMAND
T COLORADO RIVER  B          286.4 GUNNISON RIVER CONFLUENCE
T GUNNISON RIVER  H 1        298.0 GRAND JUNCTION, COLORADO
F GUNNISON RIVER  T          286.4 COLORADO RIVER CONFLUENCE
F COLORADO RIVER  J          286.4 GUNNISON RIVER JUNCTION
F COLORADO RIVER  R          257.4 IRRIGATION RETURN
F COLORADO RIVER  V 1S       217.2 STATE LINE GAGE
F COLORADO RIVER  E          200.0 TERMINAL POINT
**********
T SQUAWFISH STAGING
T SQUAWFISH DEPOSITN
T SQUAWFISH ADULT
T SQUAWFISH JUV1
T SQUAWFISH JUV2
**********
DATA FORMAT             0        0 = USGS /  1 = NWDC
```

Figure 3. Example job control file (L4JCF).

Note: At least one node must be processed. This program will stop with a fatal error if there are no nodes.

The following is the format used for each line of the species/life stages list:

Column	Format	Description
1	A1	Processing indicator: T = process this species/life stage F = do not process this species/ life stage
2	1X	Blank
3-12	10 Char	Species name (left justified)
13-22	10 Char	Life/stage name (left justified) This list must be followed by an end-of-list indicator:
1-10	A10	10 asterisks

Note: This program may be run without a species/life stages list but the end-of-list indicator is still required.

Notice that the first 10 characters of line 2 contains the units information that will be in the habitat time series output. LNKG2H assumes that the flow data file from the gaging station input is in cubic feet per second. If this should change for any reason, the program would need to be modified. In fact, it should be modified at some point to recognize the units and account for them in a general sense. The year type (calendar or water) makes no difference to LNKG2H. To get in the habit of using proper units, please follow the format given below. If you do not, a warning message will be printed.

Time codes that are in cols 1 to 3 (with a trailing :):
1 AY: = agricultural year
2 CY: = calendar year
3 WY: = water year
4 IY: = irregular year
5 = blank

Scale factors that may be in column 4:
1 none = 1.0
2 K = 1×10^3
3 M = 1×10^6
4 G = 1×10^9

Measurement units codes in cols 5-10 (left-justified):

1 ACRES = acres
2 AF = acre feet
3 CFS = cubic feet per second
4 CMS = cubic meters per second
5 DAM3 = cubic decimeters
6 GPD = gallons per day
7 HECTS = hectares
8 IRREG = irregular
9 LPD = liters per day
10 SQFT = square feet
11 SQFT/K = square feet per 1000 feet
12 SQM = square meters
13 SQM/K = square meters per 1000 meters
14 WH = watt hours
15 $ = dollars
16 = blank
17 FT = feet
18 M = meters
19 MI = miles

2.3.2 L4GAGE - Gaging Station Data file, formatted.

This file contains monthly flow data for gaging stations/nodes. It is organized by gaging stations and then by year and months within stations.

Record format:

Lines 1 and 2 - Title lines that are copied to the messages file (MESSGS) when the file is read.

Line 3 - Beginning and ending years of gage data:

Column	Format	Description
9-10	I2	Beginning year
17-18	I2	Ending year

Line 4 - Gaging station/node identifier.

Lines 5 thru N - Flow data in cfs. There are two lines for each year of flows, formatted as follows:

Column	Format	Description
(NWDC)		
17-20	I4	Year
24	I1	Data indicator: 1 = first set (months 1 thru 6) 2 = second set (months 7 thru 12)
25-66	6F7.0	Flows

Column	Format	Description
(USGS)		
13-16	I4	Year
18	I1	Data indicator (same as above)
20 thru 67	6F8.0	Flows

Lines 4 and 5 through N repeat for each new gaging station. An example of this data file is shown in Figure 4.

2.3.3 L4TMPR - Temperature Data file, formatted.

This file contains monthly temperature averages for gaging stations/ nodes. It is organized by gaging stations and then by year and month within gaging stations.

Record format:

Lines 1 and 2 - Title lines which are copied to the messages file (MESSGS) when the file is read.

Line 3 - Beginning and ending years of the temperature data within the file:

Column	Format	Description
9-10	I2	Beginning year
17-18	I2	Ending year

Line 4 - Gaging station/node identifier.

Line 5 thru N - Temperature data in Celsius. There are two lines for each year of temperatures, formatted as follows:

```
GAGING STATION DATA  -  NWDC FORMAT
CFS/MONTH
        71       80
COLORADO RIVER  H 1F       321.8 CAMEO GAGE
3 09095500      1971   1    2777   2583   2277   2248   2008   2431             M
3 09095500      1971   2    4916   8473  14870   7337   2909   2864             M
3 09095500      1972   1    2447   2309   2094   2066   2070   2458             M
3 09095500      1972   2    2936   6409  11150   3567   2317   2516             M
3 09095500      1973   1    2661   2555   2077   1894   1888   2028             M
3 09095500      1973   2    2038   9630  13920   9185   3366   2397             M
3 09095500      1974   1    2421   2376   2051   1991   1958   2472             M
3 09095500      1974   2    3109  11540  11050   4655   2615   2153             M
3 09095500      1975   1    2213   2126   1872   1769   1763   2021             M
3 09095500      1975   2    2590   6331  12420   9127   3234   2367             M
3 09095500      1976   1    2284   2241   1952   1875   1981   2261             M
3 09095500      1976   2    2707   6520   7570   3470   2423   2287             M
3 09095500      1977   1    2252   1944   1811   1715   1545   1300             M
3 09095500      1977   2    1841   2536   2959   1828   1761   1735             M
3 09095500      1978   1    1589   1393   1403   1299   1324   1564             M
3 09095500      1978   2    2892   7018  14230   5850   2196   1831             M
3 09095500      1979   1    1764   1860   1491   1349   1525   1837             M
3 09095500      1979   2    2891   9865  15050   8404   2901   2097             M
3 09095500      1980   1    2147   2127   1971   1804   1959   2028             M
3 09095500      1980   2    3168  10420  14870   5363   2381   2052             M
COLORADO RIVER  D          320.2 IRRIGATION DEMAND
3 09152500      1971   1    3059   2864   2951   3194   3622   3887             M
3 09152500      1971   2    4467   3401   3557   1859   1849   2240             M
3 09152500      1972   1    1949   2218   2343   2046   1917   1774             M
3 09152500      1972   2    1125   1877   1974    581    626   1420             M
3 09152500      1973   1    1687   2105   2552   2518   1356   1349             M
3 09152500      1973   2    1563   7410   6960   2663   2405   1842             M
3 09152500      1974   1    2031   1494   2765   3515   3844   3311             M
3 09152500      1974   2    2368   4251   2036    836    689   1091             M
3 09152500      1975   1    1368   1963   1805   1852   1735   1615             M
3 09152500      1975   2    2653   6466   5639   2679   1023   1277             M
3 09152500      1976   1    1784   2370   2477   2177   1660   1412             M
3 09152500      1976   2    1396   3371   2147    878    817   1222             M
3 09152500      1977   1    1482   1765   1944   1891   1242    774             M
3 09152500      1977   2     580    698    616    614    593    604             M
3 09152500      1978   1     807    850    704    803    821    843             M
3 09152500      1978   2    2229   4750   5284   2326    953   1438             M
3 09152500      1979   1    1102   1458   2175   2243   2796   3155             M
3 09152500      1979   2    4683   8282   6552   2910   1623   1863             M
3 09152500      1980   1    1737   1588   2385   2295   2328   2426             M
3 09152500      1980   2    3807   9109   6823   2257   1137   1277             M
```

Figure 4. Example gaging station data file (L4GAGE).

	Column	Format	Description
(NWDC)			
	17-20	I4	Year
	24	I1	Record set indicators: 1 = month 1 thru 6 2 = month 7 thru 12
	25-66	6F7.0	Temperatures
(USGS)			
	13-16	I4	Year
	18	I1	Record set indicator (same as above)
	20-67	6F8.0	Temperatures

Lines 4 and 5 through N are repeated for each new gaging station. An example of this data file is shown in Figure 5.

2.3.4 L4QA - Habitat vs. Flow Data file, formatted.

This file contains one species/life stage per record with records separated by at least 10 asterisks (**********). Record, as used here, means life stage, not a single card image and not a CDC record.

For each record:

Line 1 is a title line. This line may need to be deleted for other PHABSIM applications such as PLTTP8.

Line 2 will be the node identifier. This will correspond to a temperature model node in format, and will have to match exactly nodes read from the gaging station data.

Lines 3 and 4 will be title lines, skipped for this program, but handy to keep track of your data. Again, other PHABSIM applications may require that these titles be deleted.

Line 5 is the species line:

```
TEMPERATURE DATA ( TEST FILE )
AVERAGE DEGREES (CELCIUS)
        79       82
COLORADO RIVER  H 1F       321.8 CAMEO GAGE
 COLO321       1 1979   1   11.3    3.8     .6    1.6    4.1    5.8     WY:AVGDEGS
 COLO321       1 1979   2   10.0    9.2   12.9   19.0   19.5   15.7     WY:AVGDEGS
 COLO321       1 1980   1   10.8    5.8    3.9    3.9    4.2    7.3     WY:AVGDEGS
 COLO321       1 1980   2   11.2   13.5   16.8   20.9   20.2   17.3     WY:AVGDEGS
 COLO321       1 1981   1   11.0    5.5    1.4     .1    1.3    7.0     WY:AVGDEGS
 COLO321       1 1981   2    9.2   12.0   13.1   17.6   19.9   15.7     WY:AVGDEGS
 COLO321       1 1982   1    9.9    4.4     .8     .5    1.3    5.2     WY:AVGDEGS
 COLO321       1 1982   2    9.1   11.5   13.7   18.5   19.2   15.3     WY:AVGDEGS
COLORADO RIVER  D          320.2 IRRIGATION DEMAND
 COLO320       2 1979   1   11.3    3.7     .6    1.6    4.2    5.9     WY:AVGDEGS
 COLO320       2 1979   2   10.0    9.2   12.9   19.0   19.6   15.8     WY:AVGDEGS
 COLO320       2 1980   1   10.8    5.8    3.9    3.9    4.2    7.4     WY:AVGDEGS
 COLO320       2 1980   2   11.3   13.6   16.9   21.4   20.3   17.3     WY:AVGDEGS
 COLO320       2 1981   1   11.0    5.5    1.3     .0    1.4    7.1     WY:AVGDEGS
 COLO320       2 1981   2    9.3   12.1   13.1   17.6   20.0   15.7     WY:AVGDEGS
 COLO320       2 1982   1    9.9    4.4     .8     .4    1.4    5.2     WY:AVGDEGS
 COLO320       2 1982   2    9.2   11.6   13.7   18.6   19.3   15.4     WY:AVGDEGS
COLORADO RIVER  B          286.4 GUNNISON RIVER CONFLUENCE
 COLO286       3 1979   1   11.6    3.0     .0    1.5    4.7    6.6     WY:AVGDEGS
 COLO286       3 1979   2   11.4   10.7   13.8   20.6   21.1   16.6     WY:AVGDEGS
 COLO286       3 1980   1   10.9    5.6    3.7    3.6    4.0    7.9     WY:AVGDEGS
 COLO286       3 1980   2   13.3   16.8   19.0   29.1   21.9   18.1     WY:AVGDEGS
 COLO286       3 1981   1   10.9    5.5     .8     .0    2.5    8.2     WY:AVGDEGS
 COLO286       3 1981   2   10.9   13.9   14.2   18.9   22.0   17.0     WY:AVGDEGS
 COLO286       3 1982   1   10.7    4.5     .2     .0    2.1    6.3     WY:AVGDEGS
 COLO286       3 1982   2   10.5   12.9   14.9   20.2   20.7   16.6     WY:AVGDEGS
GUNNISON RIVER  T          286.4 COLORADO RIVER CONFLUENCE
 GUNN286       5 1979   1   13.1    6.0    1.6    3.9    4.4    6.8     WY:AVGDEGS
 GUNN286       5 1979   2    9.0    9.9   17.1   21.8   20.7   17.5     WY:AVGDEGS
 GUNN286       5 1980   1   11.6    7.3    5.8    4.5    3.7    7.9     WY:AVGDEGS
 GUNN286       5 1980   2   14.5   16.1   21.1   26.7   21.9   18.3     WY:AVGDEGS
 GUNN286       5 1981   1   10.8    5.6     .0    1.4    4.6    7.3     WY:AVGDEGS
 GUNN286       5 1981   2   10.0   12.9   17.1   21.8   21.5   17.5     WY:AVGDEGS
 GUNN286       5 1982   1   11.3    5.6    1.5    1.3    3.2    6.8     WY:AVGDEGS
 GUNN286       5 1982   2    9.9   13.3   17.6   21.5   21.0   17.1     WY:AVGDEGS
COLORADO RIVER  J          286.4 GUNNISON RIVER JUNCTION
 COLO286       6 1979   1   12.3    4.3     .6    2.7    4.5    6.7     WY:AVGDEGS
 COLO286       6 1979   2    9.9   10.3   14.7   21.1   20.9   16.9     WY:AVGDEGS
 COLO286       6 1980   1   11.1    6.3    4.6    4.0    3.9    7.9     WY:AVGDEGS
 COLO286       6 1980   2   13.3   16.4   19.7   27.8   21.9   18.1     WY:AVGDEGS
 COLO286       6 1981   1   10.9    5.5     .8     .6    3.4    7.8     WY:AVGDEGS
 COLO286       6 1981   2   10.3   13.4   14.8   19.3   21.7   17.3     WY:AVGDEGS
 COLO286       6 1982   1   10.9    4.9     .7     .6    2.6    6.6     WY:AVGDEGS
 COLO286       6 1982   2   10.3   13.0   15.5   20.6   20.8   16.8     WY:AVGDEGS
```

Figure 5. Example temperature data file (L4TMPR).

Column	Format	Description
1-10	A	Species Name
11-29	blank	
31-41	A	12 monthly flags, 1 if month applicable, 0 if not. These values are necessary at all nodes; the month's order depends on whether it is a water year or calendar year.
45-54	F10.0	Habitat threshold -- that value (in thousands of square feet), below which a warning error will be printed if the population's usable area falls below it in any month.
55-64	F10.0	Downstream distance, measured in units of miles, is the multiplier for the WUA. The downstream distance is the reach length for which one assumes that the PHABSIM hydraulics and preference criteria apply. Note that if one scenario calls for a reservoir that will inundate part or all of a 'biological' reach, you must account for that inundation by adjusting the distance factor. Also, this distance may be adjusted to account for a life stage 'weight'.

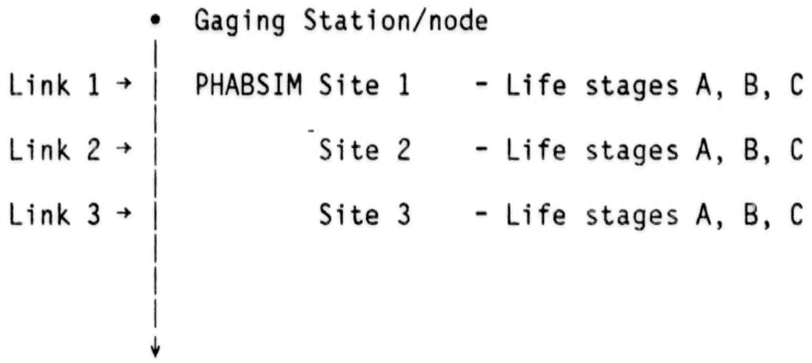
Line 6 is 'DISCHARGE' and life stage data line:

Column	Format	Description
18-27	A	Life Stage Name

Line 7 through N are the Q and WUA data (3X,2F12.0) followed by Line N+1 which is **********, End Of Logical Record. There may be a true -EOR- in the file at this point. This is optional.

Then the format repeats for each new node/life stage. The time, threshold, and distance are required for each node/life stage because they may differ throughout the network. That is, a life stage at one geographic point may have different time and threshold values than at another geographic point.

Note that there may not be more than one identical life stage referring to a single station. For example, suppose that there are three habitat sites in a single stretch of river.


Gaging Station/node
Link 1 →
PHABSIM Site 1 - Life stages A, B, C
Link 2 →
Site 2 - Life stages A, B, C
Link 3 →
Site 3 - Life stages A, B, C

If life stages A, B, and C were found at each of them, their respective curves must each refer to different stations in the gaging station input file (L4GAGE). In this case, one would need to create new or dummy gaging stations.

A useful alternative to creating new dummy stations is to combine the WUA/A data by weighting each site relative to its length to produce a single WUA/A curve. Use the following formula to combine the habitat data:

$$\frac{l_1 w_1 + l_2 w_2 + \dots l_i w_i + \dots + l_n w_n}{l_1 + l_2 + \dots + l_n}$$

where: l_i = length of reach i

w_i = weighted usable area for reach i

n = number of reaches

An example flow - WUA data file is shown in Figure 6.

```
HABITAT-FLOW FILE FOR UPPER COLORADO RIVER PROJECT. QAT1. (PARTIAL-4/III/85).
COLORADO RIVER  H 1F       321.8 CAMEO GAGE
TITLE - SQUAWFISH STAGING, HARDING HOLE (CLEOPATRA'S COUCH) SITE
LIFESTAGE - SQUAWFISH STAGING
SQUAWFISH                    000000000110   0.00       0.19
      DISCHARGE  STAGING
           0.00       0.00
         300.00   80634.59
         400.00   97489.33
         500.00  109311.99
         600.00  119996.30
         700.00  129033.76
         800.00  136558.93
         900.00  143051.08
        1000.00  147807.50
        1200.00  153243.12
        1400.00  156232.26
        1600.00  158119.40
        1800.00  159350.34
        2000.00  159776.53
        3000.00  126668.07
        4000.00   77836.52
        5000.00   51878.71
        6000.00   47077.91
        7000.00   46248.41
        8000.00   46795.53
       35000.00       0.00
      100000.00       0.00
***************
COLORADO RIVER  H 1F       321.8 CAMEO GAGE
TITLE - SQUAWFISH DEPOSITION, HARDING HOLE (CLEOPATRA'S COUCH) SITE
LIFESTAGE - SQUAWFISH DEPOSITION
SQUAWFISH                    000000000110   0.00       0.19
      DISCHARGE  DEPOSITN
           0.00       0.00
         300.00   34587.39
         400.00   44772.60
         500.00   54118.05
         600.00   62239.40
         700.00   68171.12
         800.00   73040.16
         900.00   77389.20
        1000.00   81196.07
        1200.00   87391.21
        1400.00   91881.73
        1600.00   93774.77
        1800.00   95491.56
        2000.00   96827.18
        3000.00  105372.89
        4000.00  101914.37
```

Figure 6. Example Flow - WUA Data File (L4QA).

```
        5000.00      87273.11
        6000.00      73587.83
        7000.00      63277.36
       35000.00          0.00
      100000.00          0.00
***************
```

Figure 6. (Concluded)

2.3.5 L4TSI - The temperature suitability index file contains preference curve data for each life stage. The data file is organized with one life stage per "record", with records separated by at least 10 asterisks (**********). Record, as used here, means life stage, not a single card image and not a CDC record. For each record:

Line 1 is a title line, 80 columns, free format

Line 2 contains life stage data:

cols 1-10 species name (left justified)
cols 11-20 life stage name (left justified)
cols 25-28 the word MIN, AVG or MAX
cols 30-35 temperature adjustment factor

Lines 3 through N are the temperature and SI data (5X,2F5.0)
Temperature data are assumed to be in Celsius
SI data are assumed to be between 0.0 and 1.0

Line N+1 is the logical end of record (**********)

Lines 2 to N+1 repeat for each new species/life stage. An example of this data file is shown in Figure 7. Note that a format of F5.0 means that you may either right justify an integer <u>or</u> add a decimal. Supplying the decimal is <u>highly</u> recommended.

The MIN, AVG, or MAX label tells the linkage which monthly temperature to use. The adjustment factor allows the addition of a constant value to the chosen temperature. For example, if the preference data really should indicate maximum temperature, but you felt that the aquatic species could find places in the stream to avoid the maximum temperature by 2 degrees Celsius, you should put MAX in the temperature field and -2.0 in the adjustment factor field.

```
TEMPERATURE - SUITABILITY INDEX FILE FOR TEMP. TO HABITAT MODEL TEST
SQUAWFISH ADULT          AVG  0.0
     00.0  0.0
     12.0  0.0
     15.0  0.2
     20.0  0.5
     25.0  1.0
     30.0  0.5
     32.0  0.0
**********
SQUAWFISH DEPOSITN       MAX  0.0
     00.0  0.0
     18.0  0.0
     22.0  1.0
     30.0  1.0
     32.0  0.0
     99.0  0.0
**********
SQUAWFISH STAGING        MAX  0.0
     00.0  0.0
     18.0  0.0
     22.0  1.0
     30.0  1.0
     32.0  0.0
     99.0  0.0
**********
SQUASTA
```

Figure 7. Example temperature suitability data file (L4TSI).

Note that these temperature data are not in standard PHABSIM FISHFIL data format. I decided that it would be better to have the chosen format for four reasons:

(1) No one now uses the temperature data in FISHFIL.

(2) This format is easier to edit and see what is going on.

(3) There are no restrictions such as including a zero and a 100 coordinate pair, however, it is still wise to do so.

(4) I could add additional things, such as the fudge factor and which reference (MIN, AVG, or MAX) to use.

2.4 Output files description

There are two primary output files: the habitat time series file (L4HTS), and the job summary (MESSGS).

2.4.1 L4HTS - the time series file is arranged one life stage per record.

It may be convenient to pull off one record at a time from this file by using the procedure RGET1 from the PHABSIM PROCFIL or any other source. Example output is presented in Figure 8.

Unlike a "standard" USGS or NWDC time series file, this file's station descriptor says SUM because the habitat values have been aggregated over a network and no single station identifier is relevant. The title of the habitat time series file comes directly from the job control file (L4JCF). The units also come from the first 10 characters of the job file's second title line, except that they have been divided by 1000--thus the insertion of "K".

The very small numbers, 1.E-99, represent months in which the life stage has no biological habitat value. Zero is not used, because zero might look like a realistic value. It was felt that a negative value might bomb out some other PHABSIM programs.

2.4.2 MESSGS - Job summary output file

MESSGS contains a complete description of how the job runs, the sequence of events, warning and error messages, and the summary report containing life stage statistics. You should study this output file carefully because it will be an immense help in making sure that you have set up your data files correctly. It will also be invaluable as a record of what you did to accomplish a certain option, along with the date and time of the run. An example of MESSGS is presented in Figure 9.

```
LNKG2H - GAGE DATA TO HABITAT MODEL TEST
SQUAWFISH STAGING    UNITS = WY:KSQFT        85/05/28. 15.50.55.
 SUM          1 1979   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM          1 1979   2 1.E-99 1.E-99 1.E-99  11.56  48.89 1.E-99     WY:KSQFT
 SUM          1 1980   1 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99 1.E-99     WY:KSQFT
 SUM          1 1980   2 1.E-99 1.E-99 1.E-99  36.46  81.20 1.E-99     WY:KSQFT
SQUADEP
LNKG2H - GAGE DATA TO HABITAT MODEL TEST
SQUAWFISH DEPOSITN   UNITS = WY:KSQFT        85/05/28. 15.50.57.
 SUM          2 1979   1    .00    .00    .00    .00    .00    .00     WY:KSQFT
 SUM          2 1979   2    .00    .00    .00  25.09  48.67    .00     WY:KSQFT
 SUM          2 1980   1    .00    .00    .00    .00    .00    .00     WY:KSQFT
 SUM          2 1980   2    .00    .00   3.03  75.70  67.48    .18     WY:KSQFT
SQUAADU
LNKG2H - GAGE DATA TO HABITAT MODEL TEST
SQUAWFISH ADULT      UNITS = WY:KSQFT        85/05/28. 15.50.57.
 SUM          3 1979   1    .00    .00    .00    .00    .00    .00     WY:KSQFT
 SUM          3 1979   2    .00    .00    .48   7.11  41.89  20.80     WY:KSQFT
 SUM          3 1980   1    .00    .00    .00    .00    .00    .00     WY:KSQFT
 SUM          3 1980   2    .00   1.00   2.48  30.68  45.89  28.91     WY:KSQFT
```

Figure 8. Example Habitat Time Series File (L4HTS).

```
GAGING STATION DATA TO PHYSICAL HABITAT MODEL LINKAGE
VERSION 1.3    85/05/28. 15.50.47.

FILES USED IN PROCESSING LINKAGE:
        L4JCF  = LINKAGE CONTROL FILE
        L4QA   = SPECIES LIFE STAGE Q-HA CURVE DATA FILE
        L4GAGE = GAGING STATION DATA
        L4TMPR = TEMPERATURE DATA
        L4TSI  = PREFERENCE CURVE DATA FOR TEMPERATURE
        L4HTS  = HABITAT TIME SERIES OUTPUT FILE
        MESSGS = JOB RUN INFORMATION, MESSAGES, ETC.
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
BEGIN PROCESSING GAGING DATA OUTPUT FILE
-FLOWS ASSUMED TO BE IN CFS/MONTH

GAGING STATION DATA  -  NWDC FORMAT
CFS/MONTH
FROM YEARS 1971 TO 1980
 THE GAGING DATA OUTPUT CONTAINS THE FOLLOWING NODES:
 NODE#   DESCRIPTION

    1 COLORADO RIVER  H 1F       321.8 CAMEO GAGE

    2 COLORADO RIVER  D          320.2 IRRIGATION DEMAND

    3 COLORADO RIVER  B          286.4 GUNNISON RIVER CONFLUENCE

    4 COLORADO RIVER  J          286.4 GUNNISON RIVER JUNCTION


END OF PROCESSING GAGING STATION DATA FILE.
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
BEGIN PROCESSING TEMPERATURE DATA OUTPUT FILE
 TEMPERATURES ASSUMED TO BE IN CELCIUS

TEMPERATURE DATA ( TEST FILE )
AVERAGE DEGREES (CELCIUS)
FROM YEARS 1979 TO 1982

*** WARNING ***
THE NODE:
GUNNISON RIVER  T          286.4 COLORADO RIVER CONFLUENCE
WAS ENCOUNTERED IN YOUR TEMPERATURE DATA FILE, BUT NOT FOUND IN YOUR
GAGING STATION DATA.
PROCESSING SKIPS THIS NODE COMPLETELY.
```

Figure 9. Example MESSGS report.

```
*** WARNING ***
THE NODE:
COLORADO RIVER  R          257.4 IRRIGATION RETURN
WAS ENCOUNTERED IN YOUR TEMPERATURE DATA FILE, BUT NOT FOUND IN YOUR
GAGING STATION DATA.
PROCESSING SKIPS THIS NODE COMPLETELY.

*** WARNING ***
THE NODE:
COLORADO RIVER  V 1S       217.2 STATE LINE GAGE
WAS ENCOUNTERED IN YOUR TEMPERATURE DATA FILE, BUT NOT FOUND IN YOUR
GAGING STATION DATA.
PROCESSING SKIPS THIS NODE COMPLETELY.

*** WARNING ***
THE NODE:
COLORADO RIVER  E          200.0 TERMINAL POINT
WAS ENCOUNTERED IN YOUR TEMPERATURE DATA FILE, BUT NOT FOUND IN YOUR
GAGING STATION DATA.
PROCESSING SKIPS THIS NODE COMPLETELY.
 THE TEMPERATURE DATA OUTPUT CONTAINS THE FOLLOWING NODES:
 NODE#   DESCRIPTION

    1 COLORADO RIVER  H 1F       321.8 CAMEO GAGE

    2 COLORADO RIVER  D          320.2 IRRIGATION DEMAND

    3 COLORADO RIVER  B          286.4 GUNNISON RIVER CONFLUENCE

    4 COLORADO RIVER  J          286.4 GUNNISON RIVER JUNCTION


END OF PROCESSING TEMPERATURE DATA FILE (L4TMPR).

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
CHECKING SPECIES/LIFE STAGE Q-WUA DATA FILE:
NODE#     DESCRIPTION
    LIFE STAGE DATA (MONTHS CORRESPOND TO GAGING INPUT)

HABITAT-FLOW FILE FOR GAGE DATA TO HABITAT MODEL TEST.  TL4QA.

------------------------------------------------------------------------------
  1 COLORADO RIVER  H 1F       321.8 CAMEO GAGE
   1 SQUAWFISH STAGING    HAS  22 FLOW DATA POINTS
       MONTHS = 000000000110  THRESHOLD =       .00  DISTANCE =       .19 MI.

------------------------------------------------------------------------------
  1 COLORADO RIVER  H 1F       321.8 CAMEO GAGE
   2 SQUAWFISH DEPOSITN   HAS  21 FLOW DATA POINTS
       MONTHS = 000000000110  THRESHOLD =       .00  DISTANCE =       .19 MI.
```

Figure 9. (Continued)

```
--------------------------------------------------------------------------------
   1 COLORADO RIVER  H 1F       321.8 CAMEO GAGE
    3 SQUAWFISH ADULT      HAS  30 FLOW DATA POINTS
       MONTHS = 111111111111  THRESHOLD =       .00  DISTANCE =      .19 MI.

--------------------------------------------------------------------------------
   3 COLORADO RIVER  B          286.4 GUNNISON RIVER CONFLUENCE
    2 SQUAWFISH DEPOSITN   HAS  22 FLOW DATA POINTS
       MONTHS = 111111111111  THRESHOLD =       .00  DISTANCE =      .19 MI.

*** WARNING ***

THE NODE:
GUNNISON RIVER  T          286.4 COLORADO RIVER CONFLUENCE
WAS ENCOUNTERED IN YOUR Q-WUA DATA FILE,
BUT NOT FOUND IN YOUR GAGING STATION NODES.
PROCESSING SKIPS THIS NODE COMPLETELY.

*** WARNING ***
THE NODE:
COLORADO RIVER  E          200.0 TERMINAL POINT
WAS ENCOUNTERED IN YOUR Q-WUA DATA FILE,
BUT NOT FOUND IN YOUR GAGING STATION NODES.
PROCESSING SKIPS THIS NODE COMPLETELY.

*** WARNING ***
THE NODE:
YAMPA RIVER     S   5      652.0 CROSS MOUNTAIN
WAS ENCOUNTERED IN YOUR Q-WUA DATA FILE,
BUT NOT FOUND IN YOUR GAGING STATION NODES.
PROCESSING SKIPS THIS NODE COMPLETELY.

*** WARNING ***
THE NODE:
YAMPA RIVER     T          556.7 GREEN RIVER CONFLUENCE
WAS ENCOUNTERED IN YOUR Q-WUA DATA FILE,
BUT NOT FOUND IN YOUR GAGING STATION NODES.
PROCESSING SKIPS THIS NODE COMPLETELY.

*** WARNING ***
THE NODE:
YAMPA RIVER     C          585.7 HARDING HOLE
WAS ENCOUNTERED IN YOUR Q-WUA DATA FILE,
BUT NOT FOUND IN YOUR GAGING STATION NODES.
PROCESSING SKIPS THIS NODE COMPLETELY.
```

Figure 9. (Continued)

```
*** WARNING ***
THE NODE:
YAMPA RIVER     C          585.7 HARDING HOLE
WAS ENCOUNTERED IN YOUR Q-WUA DATA FILE,
BUT NOT FOUND IN YOUR GAGING STATION NODES.
PROCESSING SKIPS THIS NODE COMPLETELY.

*** WARNING ***
THE NODE:
YAMPA RIVER     C          585.7 HARDING HOLE
WAS ENCOUNTERED IN YOUR Q-WUA DATA FILE,
BUT NOT FOUND IN YOUR GAGING STATION NODES.
PROCESSING SKIPS THIS NODE COMPLETELY.

*** WARNING ***
THE NODE:
YAMPA RIVER     S   5      652.0 CROSS MOUNTAIN
WAS ENCOUNTERED IN YOUR Q-WUA DATA FILE,
BUT NOT FOUND IN YOUR GAGING STATION NODES.
PROCESSING SKIPS THIS NODE COMPLETELY.

END OF CHECKING SPECIES/LIFE STAGE Q-WUA DATA FILE
YOU HAVE   4 ENTRIES AND   3 UNIQUE LIFE STAGE(S).

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
CHECKING SPECIES/LIFE STAGE TEMPERATURE-SI DATA FILE:
TEMPERATURE - SUITABILITY INDEX FILE FOR TEMP. TO HABITAT MODEL TEST

    3 SQUAWFISH ADULT         AVG      .00 DEG
     HAS  7 DATA POINTS.
    2 SQUAWFISH DEPOSITN      MAX      .00 DEG
     HAS  6 DATA POINTS.
    1 SQUAWFISH STAGING       MAX      .00 DEG
     HAS  6 DATA POINTS.

END OF READING SPECIES/LIFE STAGE TEMPERATURE-SI DATA FILE.
YOU HAVE  3 LIFE STAGES REPRESENTED.

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
PROCESSING YOUR JOB CONTROL FILE:

    LNKG2H - GAGE DATA TO HABITAT MODEL TEST
    WY: SQFT
     UNITS = WY: SQFT
    FIRST YEAR = 1971
```

Figure 9. (Continued)

```
*** WARNING ***
THE FIRST YEAR REQUESTED 1971
IS OUT OF BOUNDS OF CORRESPONDING GAGING STATION AND TEMPERATURE DATA
I WILL START WITH THE FIRST YEAR OF CORRESPONDING DATA - 1979.
    LAST YEAR  = 1982

*** WARNING ***
THE LAST YEAR REQUESTED  1982
IS GREATER THAN THE LAST YEAR OF GAGING DATA 1980
I WILL END WITH THE LAST YEAR OF GAGING INSTEAD.

FINISHED VERIFYING INCLUSIVE YEARS FROM JOB CONTROL, GAGING, AND TEMPERATURE
DATA FILES.  YOUR TEMPERATURE CONDITIONED HABITAT TIME SERIES DATA WILL BE
PRODUCED FOR YEARS 1979 THROUGH 1980

    MONTHS = 111111111111


   NODES LIST

 1 COLORADO RIVER  H 1F       321.8 CAMEO GAGE
 2 COLORADO RIVER  D          320.2 IRRIGATION DEMAND
 3 COLORADO RIVER  B          286.4 GUNNISON RIVER CONFLUENCE

*** WARNING ***
THE FOLLOWING NODE:
   GUNNISON RIVER  H 1        298.0 GRAND JUNCTION, COLORADO
IS INVALID OR NOT FOUND - IT WILL BE  EXCLUDED FROM PROCESSING.

   LIFE STAGES LIST

 1 SQUAWFISH STAGING
 2 SQUAWFISH DEPOSITN
 3 SQUAWFISH ADULT

*** WARNING ***
THE FOLLOWING LIFE STAGE:
   SQUAWFISH JUV1
IS INVALID OR NOT FOUND - IT WILL BE EXCLUDED FROM PROCESSING

*** WARNING ***
THE FOLLOWING LIFE STAGE:
   SQUAWFISH JUV2
IS INVALID OR NOT FOUND - IT WILL BE EXCLUDED FROM PROCESSING


    HTS DATA FMT =    0

END OF PROCESSING JOB CONTROL FILE.
```

Figure 9. (Continued)

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * 
BEGINNING TO GENERATE HABITAT TIME SERIES      85/05/28. 15.50.55.


FOR SPECIES/LIFE STAGE: SQUAWFISH STAGING
TEMPERATURE CONDITIONED HABITAT TIME SERIES DATA WILL BE PRODUCED.


         1 SQUAWFISH STAGING
           = SQUASTA


FOR SPECIES/LIFE STAGE: SQUAWFISH DEPOSITN
TEMPERATURE CONDITIONED HABITAT TIME SERIES DATA WILL BE PRODUCED.


         2 SQUAWFISH DEPOSITN
           = SQUADEP


FOR SPECIES/LIFE STAGE: SQUAWFISH ADULT
TEMPERATURE CONDITIONED HABITAT TIME SERIES DATA WILL BE PRODUCED.


         3 SQUAWFISH ADULT
           = SQUAADU

END OF HABITAT TIME SERIES GENERATION
DATA IS ON FILE "L4HTS"

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * 
BEGIN THE REPORT SECTION

==============================================================================
    1 SQUAWFISH STAGING
         MINIMUM AREA ENCOUNTERED =        12.
             IN YEAR 1979 MONTH 10
        AVERAGE AREA =        45. KSQFT    PER MONTH
         MINIMUM AREA ENCOUNTERED =       81.
             IN YEAR 1980 MONTH 11
 NODE  PERCENT  DESCRIPTION
-------------------------------------------------------------------------------
     1   100     COLORADO RIVER  H 1F       321.8 CAMEO GAGE
       -------
        100%

==============================================================================
```

Figure 9. (Continued)

```
    2 SQUAWFISH DEPOSITN
          MINIMUM AREA ENCOUNTERED =        0.
              IN YEAR 1979 MONTH  1
         AVERAGE AREA =         8. KSQFT   PER MONTH
          MINIMUM AREA ENCOUNTERED =       76.
              IN YEAR 1980 MONTH 10
 NODE  PERCENT  DESCRIPTION
--------------------------------------------------------------------------------
     1    76      COLORADO RIVER  H 1F       321.8 CAMEO GAGE
     3    23      COLORADO RIVER  B          286.4 GUNNISON RIVER CONFLUENCE
       -------
        100%

===============================================================================
-   3 SQUAWFISH ADULT
          MINIMUM AREA ENCOUNTERED =        0.
              IN YEAR 1979 MONTH  1
         AVERAGE AREA =         7. KSQFT   PER MONTH
          MAXIMUM AREA ENCOUNTERED =       46.
              IN YEAR 1980 MONTH 11
 NODE  PERCENT  DESCRIPTION
--------------------------------------------------------------------------------
     1   100      COLORADO RIVER  H 1F       321.8 CAMEO GAGE
       -------
        100%


THAT'S ALL FOLKS -- NORMAL END OF JOB

THERE WERE   0 FATAL ERROR(S) IN THIS LINKRUN
     AND  13 WARNING ERROR(S).
```

Figure 9. (Concluded)

Past the run summary, the REPORT section should be of particular significance. This section lists for each species/life stage:

1. Life stage name
2. Minimum area encountered
3. When minimum occurred (if more than one time, only first one is reported)
4. Average area encountered
5. Maximum area encountered
6. When maximum is encountered (if more than one time, only first one is reported)
7. Percentage of total area contributed by each node

2.5 Defaults

The only default conditions used in LNKG2H pertain to the job control file. If data in that file are out of range, then the defaults are to use the first and last years of gaging station data and use all months. If there are no gaging stations/nodes in the nodes list or an unexpected end-of-file is reached, then the program stops with a fatal error.

The default habitat time series data file (L3HTS) format is USGS.

3.0 RELATED SOFTWARE

3.1 Precursors

There are at least two precursors to running LNKG2H: PHABSIM and assembling your gaging station data. Both are well beyond the scope of this documentation. However, there are are a few hints to be passed along.

Station data. When setting up your gaging station data set you must remember to account for the physical habitat sites in the network description. General guidelines would call for establishing a node wherever there is likely to be a change in flow of greater than 10 percent through a habitat site. In this way, accurate translation of flow to habitat value may be retained.

PHABSIM. Aside from assembling all of the habitat vs. flow data files (known as TAPE8s in PHABSIM) into a single file, there remains at least one important task. The upper and lower bounds of each curve should be examined for their ability to handle the extremes of yearly flows likely to be encountered in a HYDROSS run. LNKG2H does no curve extrapolation as do some other PHABSIM routines. If a flow is encountered outside the bounds of a life stage's curve, the habitat value is set to zero. A warning message is provided, but it is the user's responsibility to provide reasonable extrapolations or accept the consequences. This approach is more prudent than extrapolation, because pure mathematical extrapolation is not often hydrologically or biologically acceptable.

3.2 Postcursors

We have made much use of PHABSIM plotting and duration analysis programs to continue the analysis of the results of LNKG2H. Typically, you would use RGET1 to extract single life stages as records from the habitat time series file (L4HTS) to be used as input to programs such as LPTDUR and LPTTSN. In the future, links to the effective habitat time series programs should be performed in the same way.

3.3 Alternative Methods

There are no alternatives at this time.

4.0 LIMITATIONS

4.1 Accuracy

LNKG2H contains only one mathematical relationship beyond simple format statement kinds of accuracy limitations. The interpolation to calculate WUA given the flow is strictly linear. All constants used to change units have at least four decimal places.

4.2 Assumptions

LNKG2H assumes that the gaging station flows are in units of cubic meters per second, that stream lengths are in miles, and that the WUA units are square feet per 1000 feet of stream. Beyond these, units-in will always equal units-out; though the print out may refer to constant units.

Though calculations are independent of any given time step, the output files do assume monthly format.

4.3 Constraints

Current program limits are listed as follows. However, most limits may be changed by altering the parameter statements in the source code and recompiling.

Maximum Number of Nodes/Gaging Stations	40	
Maximum Number of Life Stages	10	
Maximum Number of Points in HA vs. Q Curve	30	
Maximum Number of years	none	
Maximum Number of Time Steps/Year	12	
Minimum Number of Time Steps/Year	12	- should not be changed
Maximum Number of Points in a T-SI Curve	15	

5.0 MESSAGES

Messages are divided into two categories, warning and fatal. These are listed separately, approximately in the order in which they might be encountered. In general, warning messages will not cause program termination; the job will do its best to continue. Fatal errors, however, will cause either immediate or delayed job termination, depending on the circumstances. The output file (OUTPUT) will provide a run summary for these messages. The messages file (MESSGS) will show the messages in their entirety.

5.1 Warning Messages

a.
```
*** WARNING ***
GAGING STATION DATA CONTAINS ____ NODES.
I ONLY HAVE ROOM FOR ____.
I WILL CONTINUE WITH THE MAXIMUM ALLOWED.
```

b.
```
*** WARNING ***
TEMPERATURE DATA CONTAINS ____ NODES.
I ONLY HAVE ROOM FOR ____.
I WILL CONTINUE WITH THE MAXIMUM ALLOWED.
```

c.
```
*** WARNING ***
THE NODE:

_________
WAS ENCOUNTERED IN YOUR TEMPERATURE DATA FILE
BUT NOT FOUND IN YOUR GAGING STATION DATA.
PROCESSING SKIPS THIS NODE COMPLETELY.
```

d.
```
*** WARNING ***
UNEXPECTED END FOUND ON TEMPERATURE DATA FILE
(L4TMPR), OR
OPTIONAL TEMPERATURE DATA NOT PROVIDED.
```

e.
```
*** WARNING ***
THE NODE
_________ WAS ENCOUNTERED IN YOUR Q-WUA DATA FILE,
BUT NOT FOUND IN YOUR GAGING STATION NODES FILE.
PROCESSING SKIPS THIS NODE COMPLETELY.
```

You may feel free to have a large data base of curves and not refer to them in your linkage.

f.
```
*** WARNING *** BAD SPECIES LIFE STAGE ___ FOUND IN FILE. I WILL
TRY TO RECOVER.
```

Check your curve data file (L4QA) for incorrect number of title lines, no **********, or something like that. Also check your T-SI curve data file (L4TSI).

g. *** WARNING *** EXPECTED A NEW LIFE STAGE BUT FOUND AN END OF FILE. I WILL TRY TO CONTINUE.

Check card sequence in curve data file (L4QA).

h. *** WARNING *** TOO MANY UNIQUE LIFE STAGES ENCOUNTERED. I CAN ONLY HANDLE ___. I WILL CONTINUE WITH WHAT I HAVE.

Either remove unessential life stages or recompile program with new parameters.

i. *** WARNING *** TOO MANY POINTS IN CURVE. I ONLY HAVE ROOM FOR ___. I WILL TRY TO RECOVER.

Either remove unessential points or recompile program with new parameters. This warning refers to the curve data in either L4QA or L4TSI.

j. *** WARNING *** FLOW DATA NOT INCREASING. CHECK DATA FILE FOR flow IN node.

Succeeding flows must increase from record to record to be able to interpolate properly. Check your L4QA data file.

k. *** WARNING *** THIS NODE HAS NO FLOW-WUA DATA POINTS. I WILL TRY TO CONTINUE.

l. *** WARNING *** LIFE STAGE ______ FOUND IN FILE, BUT WAS NOT FOUND IN YOUR Q-WUA FILE. I WILL SKIP THIS RECORD.

The reported life stage was found in L4TSI but not found in L4QA.

m. *** WARNING *** EXPECTED MIN, AVG, OR MAX, BUT FOUND _____ INSTEAD. REFERENCE SET TO AVG.

Check formatting in L4TSI.

n. *** WARNING *** TEMPERATURE DATA NOT INCREASING. CHECK DATA FILE FOR _______ IN ______.

Check T-SI curve values in L4TSI.

o. *** WARNING *** SI VALUE NOT BETWEEN ZERO AND ONE. CHECK DATA FILE FOR _______ COORDINATES SKIPPED. I WILL TRY TO CONTINUE.

Check L4TSI.

p. *** WARNING *** THIS LIFE STAGE HAS NO DATA POINTS. I WILL TRY TO CONTINUE.

Check L4TSI.

q. *** WARNING *** THE FIRST YEAR REQUESTED ___ IS OUT OF BOUNDS OF GAGING DATA. I WILL START WITH THE FIRST YEAR OF GAGING DATA INSTEAD.

You probably put 1960 instead of 60, for example.

r. *** WARNING *** THE FIRST YEAR REQUESTED _______ IS OUT OF BOUNDS OF CORRESPONDING GAGING STATION AND TEMPERATURE DATA. I WILL START WITH THE FIRST YEAR OF CORRESPONDING DATA-_____.

If this start year is not correct then check the start dates in the temperature data (L4TMPR) and the gaging station data (L4GAGE).

s. *** WARNING *** THE LAST YEAR REQUESTED ___ IS GREATER THAN THE LAST YEAR OF GAGING DATA ___. I WILL END WITH THE LAST YEAR OF GAGING DATA INSTEAD.

Ditto above.

t. *** WARNING *** THE LAST YEAR REQUESTED IS OUT OF BOUNDS OF CORRESPONDING GAGING STATION AND TEMPERATURE DATA. I WILL END WITH THE LAST YEAR OF CORRESPONDING DATA-_____.

If this last year is not correct then check the last year dates in the temperature data (L4TMPR) and the gaging station data (L4GAGE).

u. *** WARNING *** YOUR REQUESTED MONTHS WERE BLANK. YOU SHOULD SPECIFY THEM. I WILL PROCEED WITH THEM ALL TURNED ON.

Check the format for the species line in file L4QA.

v. *** WARNING *** THE MAXIMUM NUMBER OF ___ NODES HAS BEEN EXCEEDED. THE FOLLOWING NODE:

____

WILL NOT BE INCLUDED IN PROCESSING.

Processing will continue with the maximum nodes.

w. *** WARNING *** THE FOLLOWING NODE:

____

IS INVALID OR NOT FOUND - IT WILL BE EXCLUDED FROM PROCESSING.

You possibly asked for a non-existent node. Also check for spelling and/or formatting errors in L4JCF.

x. *** WARNING ***

THE MAXIMUM NUMBER OF ______ LIFE STAGES HAS BEEN EXCEEDED. THE FOLLOWING LIFE STAGE:

____

WILL NOT BE INCLUDED IN PROCESSING.

Processing will continue with the maximum life stages.

y. *** WARNING *** THE FOLLOWING LIFE STAGE:

____

IS INVALID OR NOT FOUND - IT WILL BE EXCLUDED FROM PROCESSING.

You possibly asked for a non-existent life stage. Also check for spelling and/or formatting errors in L4JCF.

z. *** WARNING *** NO VALID LIFE STAGES WERE FOUND IN L4JCF
PROCESSING WILL CONTINUE WITHOUT LIFE STAGES

aa. *** WARNING *** ILLEGAL FORMAT REQUESTED. I WILL DEFAULT TO 0.

Probably a typo or wrong column in L4JCF.

bb. *** WARNING *** FOUND ___ INSTEAD OF PROPER UNITS.

Consult units tables for legitimate options.

cc. *** WARNING ***
THE LIFE STAGE:

___life stage___

WILL NOT BE PROCESSED. THE TIME SERIES DATA THAT WOULD BE PRODUCED WOULD BE PARTIALLY TEMPERATURE CONDITIONED AND PARTIALLY NOT - THIS DATA WOULD BE ERRONEOUS.

If this was not anticipated then check the correlation of data for this life stage. Ensure, especially, that all temperature data necessary for this life stage has been made available.

dd. *** WARNING *** FOR life stage AT node, FLOW OF ___ IS BELOW LOWEST FLOW IN Q-HA RELATIONSHIP.

Zero will be used. You should supply interpolation.

ee. *** WARNING *** FOR Life Stage AT Node, FLOW OF ___ IS GREATER THAN HIGHEST FLOW IN Q-HA CURVE.

Zero will be used. You should supply interpolation.

ff. YEAR = MONTH = ________ FLOW OF _______ PROVIDED AN AREA OF _____.
THIS IS BELOW YOUR THRESHOLD OF ______ KSQFT.

This relates to the threshold value on your species line in L4QA data file.

gg. *** WARNING ***
FOR: ________________ AT

____

TEMPERATURE OF _____ IS BELOW LOWEST POINT IN T-SI CURVE.
*** NO SUITABILITY INDEX WILL BE CALCULATED ***
*** YOUR TIME SERIES DATA MAY BE ERRONEOUS ***

hh. *** WARNING ***
FOR: _______________ AT
____
TEMPERATURE OF _____ IS ABOVE HIGHEST POINT IN T-SI CURVE.
*** NO SUITABILITY INDEX WILL BE CALCULATED ***
*** YOUR TIME SERIES DATA MAY BE ERRONEOUS ***

5.2 Fatal messages

a. $$$ FATAL ERROR: DID NOT GET SUFFICIENT DATA FROM LIFE STAGE FILE TO CONTINUE WITH PROCESSING.

You must have at least one valid node/life stage with at least 1 data point. Chances are you goofed on this data file (L4QA).

b. $$$ FATAL ERROR: NO VALID NODES WERE FOUND IN L4JCF FILE. PROCESSING CANNOT CONTINUE.

There must be at least one valid node in the L4JCF nodes list in order to execute this program. Check formatting and spelling in L4JCF.

c. $$$ FATAL ERROR $$$ UNEXPECTED END FOUND ON JOB CONTROL FILE. PROCESSING CANNOT CONTINUE.

Check formatting of L4JCF file.

d. $$$ FATAL ERROR
UNEXPECTED END FOUND ON GAGING STATION DATA FILE.

e. $$$ FATAL $$$
UNEXPECTED PROBLEM WITH INTERNAL SCRATCH FILE (IOSCR)
THE GAGING STATION DATA IS READ INTO THIS INDEXED FILE.

This error may be caused by an incorrect version of the temporary file TAPE98. After careful checking, see a systems analyst.

f. $$$ FATAL ERROR
PROBLEM WITH SCRATCH FILE IN SUBROUTINE WRITHTS.

g. $$$ FATAL $$$
UNEXPECTED PROBLEM WITH INTERNAL SCRATCH FILE (IOSCRT)
THE TEMPERATURE DATA IS READ INTO THIS FILE.

h. $$$ FATAL ERROR $$$
THERE WAS NO DATA FOR REQUESTED YEARS ... OR ...
THERE WERE NO CORRESPONDING YEARS OF GAGING STATION AND TEMPERATURE DATA.
PROCESSING CANNOT CONTINUE.

6.0 TIME/COST

A run for 11 years at 22 gaging stations may cost $2.

These estimates, of course, do not include time to set up and debug data files. Though difficult to estimate, please allow up to 2 days to really get started. This ignores setting up and running the temperature model.

7.0 UNUSUAL APPLICATIONS -- None.

8.0 POSSIBLE MODIFICATIONS

The error needs to be fixed and units properly recognized instead of trusted.

9.0 SUPPLEMENTAL MATERIAL

See also the PHABSIM, HYDROSS, and TEMPERATURE MODEL documentation. Also refer to documentation for LNKQ2T.

10.0 HARDWARE

1. Standard - Any system supporting standard FORTRAN 77.
2. Required peripherals - none.

11.0 ACKNOWLEDGEMENTS

Development of this program was paid for by U.S. Fish and Wildlife Service, Region 6 (Denver).

APPENDIX E

TITLE -- LNKT2TS (Temperature Model to Time Series Program) Version 1.1

AUTHORS -- John Bartholow
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U.S. Fish & Wildlife Service
Western Energy and Land Use Team
May 1985

1.0 INTRODUCTION

This program provides a way to generate flow and temperature time series data files from the stream network temperature model. It will read the binary data file created by the temperature model (KTRNSPT) and then generate the time series files for one or more geographic locations.

Input data are provided by the temperature model and the primary output is in the form of a U.S. Geological Survey (USGS) or Northwest Data Center (NWDC) monthly time series data file. The time series data may then be used in subsequent time series manipulations such as plots and duration analyses.

This program is a member of a family of programs in the network habitat analysis family. This group includes:

LNKQ2T - HYDROSS to TEMPERATURE MODEL
LNKT2H - TEMPERATURE to HABITAT MODEL
LNKQ2H - HYDROSS to HABITAT MODEL
LNKG2H - GAGE DATA to HABITAT MODEL
LNKT2TS - TEMPERATURE TO TIME SERIES PROGRAM (this program)

1.1 Execution Procedure

This program can be run in BATCH mode.

```
 EOI ENCOUNTERED.
/GET,DL5BAT
/COPY,DL5BAT
/JOB
SNAB,P2.
/USER
/CHARGE,*.
COMMENT. P2 = DEFAULT
COMMENT. P3 = 6PM TO 6AM
COMMENT. P5 = SAT, SUN & HOLIDAYS
PURGE,QOUT/NA.
DEFINE,QOUT.
GET,L5JCF = JOB CONTROL FILE.
```

```
GET,KTRNSPT = TEMPERATURE MODEL OUTPUT.
GET,LNKT2TS.
LNKT2TS.
REWIND,*.
COPY,OUTPUT,QOUT.
COPY,MESSGS,QOUT.
COPYSBF,L5QTS,QOUT.
COPYSBF,L5TTS,QOUT.
REWIND,QOUT.
COPY,QOUT,QQ.
DAYFILE,QA.
REPLACE,QA.
EXIT.
STATUS,F.
REWIND,*.
COPY,OUTPUT,QOUT.
COPY,MESSGS,QOUT.
COPYSBF,L5QTS,QOUT.
COPYSBF,L5TTS,QOUT.
COPY,PMDUMP,QOUT.
DAYFILE,QAA.
REPLACE,QAA.
```

2.0 APPLICATION

It is assumed that you have run the temperature model with a sufficient node network. If so, this linkage operates as follows:

2.1 Description of Logic

From a user's perspective, LNKT2TS does these things:

2.1.1 Opens and rewinds all files necessary for operation (Figure 1).

Input:

- KTRNSPT - Temperature model random access output file, must be local
- L5JCF - Job control file, must be local

Output:

- OUTPUT - For brief program termination messages
- MESSGS - For run status, error messages and summary report. This file is rewound at the end of the run.
- L5QTS - For the flow time series data for subsequent input into PHABSIM routines.
- L5TTS - Formatted temperature time series data.

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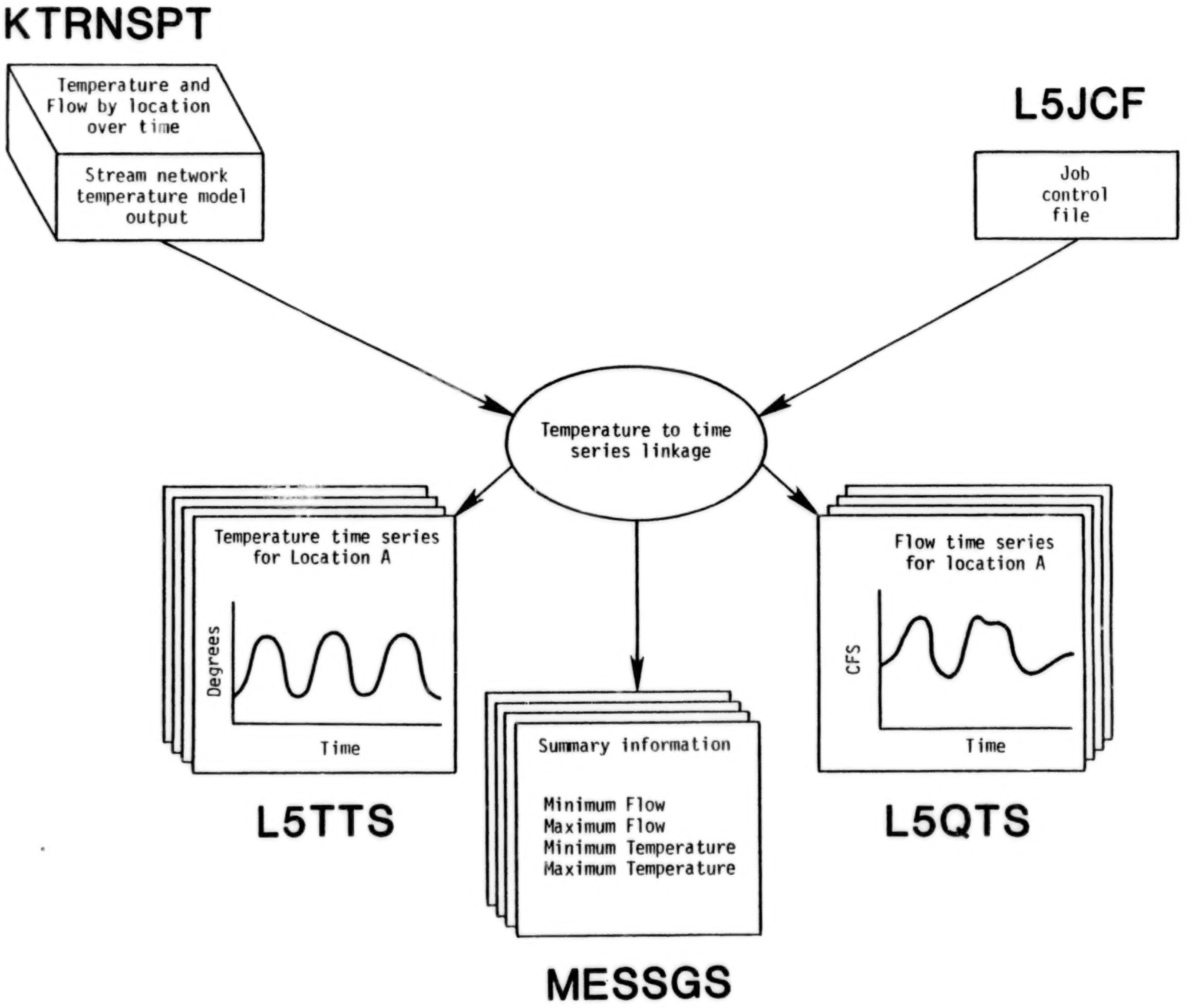
KTRNSPT
Temperature and Flow by location over time
Stream network temperature model output
L5JCF
Job control file
Temperature to time series linkage
Temperature time series for Location A
Degrees
Time
L5TTS
Summary information
Minimum Flow
Maximum Flow
Minimum Temperature
Maximum Temperature
MESSGS
Flow time series for location A
CFS
Time
L5QTS

Figure 1. Essential input and output files for the temperature to time series program.

2.1.2 Reads the temperature model output file from the transport model (KTRNSPT). This output file tells LNKT2TS how many nodes, years, and time periods exist in the file. KTRNSPT is a binary, random access file and must not be edited using XEDIT.

The printed equivalent of this file may be obtained from the temperature model.

The routine will list to the MESSGS file the node names and their assigned node numbers.

2.1.3 Reads the Job Control File (L5JCF). The job file is the primary way to control most options in the program including which years or months to use. An example of a job control file is shown in Figure 2.

2.2 Options

The primary options for this program are controlled by the job control data file (L5JCF) (Figure 2). Through the proper use of this file, you may control which nodes to aggregate, and what time period, both in years and months, is to be covered. In this way, comparisons may easily be made across both time and space for any biological requirement.

2.3 Input Files Description

2.3.1 L5JCF -- Job Control File, formatted

The job control file may be used to control the overall execution of this program. An example of the job control file is shown in Figure 2.

The title that ends up on the flow time series file (L5QTS) and the temperature time series file (L5TTS) is the first title line in the job control file.

The first year of data requested (79 in the example) refers to the calendar or water year from the temperature model output file (KTRNSPT). The number following the first year is the starting year of the temperature model. Unfortunately, the KTRNSPT file does not contain the data needed to tell which years are what. Thus, in this case we must tell the linkage that KTRNSPT begins in year 79. Note that all years should be truncated to the last two digits. Thus, 1972 becomes 72.

The last year (82) refers to the last year of temperature model output you want processed.

The 12 time period flags almost always will refer to the months of temperature model output. If 1, that month will be processed; if 0, that month will be skipped. The months will always be in the order specified by the units, calendar year, or water year.

```
TEMP. MODEL TO TIME SERIES LINK; PRESENT LEVEL LEVEL DATA - 31 DEC 84
WY: CFS
FIRST YEAR            79   79
LAST YEAR             82
MONTHS              111111111111
T COLORADO RIVER  H 1F      321.8 CAMEO GAGE
T COLORADO RIVER  D         320.2 IRRIGATION DEMAND
T COLORADO RIVER  B         286.4 GUNNISON RIVER CONFLUENCE
T GUNNISON RIVER  H 1       298.0 GRAND JUNCTION, COLORADO
T GUNNISON RIVER  T         286.4 COLORADO RIVER CONFLUENCE
T COLORADO RIVER  J         286.4 GUNNISON RIVER JUNCTION
T COLORADO RIVER  R         257.4 IRRIGATION RETURN
T COLORADO RIVER  V 1S      217.2 STATE LINE GAGE
T COLORADO RIVER  E         200.0 TERMINAL POINT
**********
TAPE10 DATA FMT        0     0 FOR USGS; 1 FOR NWDC
TEMPERATURE REF               AVG    0.0
```

Figure 2. Example job control file (L5JCF).

The nodes list may contain any number of descriptions. A "T" is used in column one to indicate which nodes are to be used in processing. An "F" is used in column one to indicate nodes that should not be processed.

The following is the format used for each line of the nodes list:

Column	Format	Description
1	A1	Processing indicator: T = process this node F = do not process this node
2	1X	Blank
Node Identifier:		
3-18	16 Char	Stream name
19-26	8 Char	Node type
27-34	F8.1	Stream distance
35-80	46 Char	Stream location remark Note: this remark is 2 characters shorter than normal-ensure that uniqueness was not previously established by the last 2 characters This list must be followed by an end-of-list indicator:
1-10	A10	10 asterisks

Note: At least one node must be processed. This program will stop with a fatal error if there are no nodes.

Notice that the first 10 characters of line 2 contain the units information that will be in the flow time series output. LNKT2TS assumes that the flow data file from the temperature model is in cubic meters per second. If this should change for any reason, the program would need to be modified. In fact, it should be modified at some point to recognize the units and account for them in a general sense. The year type (calendar or water) makes no difference to LNKT2TS. To get in the habit of using proper units, please follow the format given below. If you do not, a warning message will be printed.

Time codes that are in cols 1 to 3 (with a trailing :):

1 AY: = agricultural year
2 CY: = calendar year
3 WY: = water year
4 IY: = irregular year
5 = blank

Scale factors that may be in column 4:
1 none = 1.0
2 K = 1×10^3
3 M = 1×10^6
4 G = 1×10^9

Measurement units codes in cols 5-10 (left-justified):
1 ACRES = acres
2 AF = acre feet
3 CFS = cubic feet per second
4 CMS = cubic meters per second
5 DAM3 = cubic decimeters
6 GPD = gallons per day
7 HECTS = hectares
8 IRREG = irregular
9 LPD = liters per day
10 SQFT = square feet
11 SQFT/K = square feet per 1000 feet
12 SQM = square meters
13 SQM/K = square meters per 1000 meters
14 WH = watt hours
15 $ = dollars
16 = blank
17 FT = feet
18 M = meters
19 MI = miles

2.4 Output Files Description

There are three primary output files: the flow time series file (L5QTS), temperature time series file (L5TTS), and the job summary (MESSGS).

L5QTS. Flow time series file is arranged by nodes. The title of this file comes directly from the first title line of the job control file (L5JCF). The units also come from the first 10 characters of the job file's second title line. Example output is presented in Figure 3.

L5TTS. Temperature time series file is arranged by nodes. The title line of this file also comes from the job control file. Example output is presented in Figure 4.

MESSGS. Job summary output file. MESSGS contains a complete description of how the job runs, the sequence of events, and warning and error messages. You should study this output file carefully because it will be an immense help in making sure that you have set up your data files correctly. It will also be invaluable as a record of what you did to accomplish a certain option, along with the date and time of the run. An example of MESSGS is presented in Figure 5.

```
COLO321      85/04/24. 14.02.53.
TEMP. MODEL TO TIME SERIES LINK; PRESENT LEVEL LEVEL  DATA - 31 DEC 84
COLORADO RIVER  H 1F        321.8 CAMEO GAGE
 COLO321        1 1979    1 1832.8 2021.7 1917.4 1868.6 2158.8 2112.6    WY: CFS
 COLO321        1 1979    2 2806.5 8993.514810.5 4929.4 1676.8 1794.8    WY: CFS
 COLO321        1 1980    1 1735.3 1786.4 1657.2 1611.7 1568.3 1502.7    WY: CFS
 COLO321        1 1980    2 2067.0 2550.1 4376.1 1642.6  910.7 1761.2    WY: CFS
 COLO321        1 1981    1 1897.9 1719.2 1575.9 1806.8 1622.3 1909.3    WY: CFS
 COLO321        1 1981    2 2206.5 5773.511936.8 8328.4 3433.2 3324.1    WY: CFS
 COLO321        1 1982    1 2042.4 1886.3 1685.4 1602.7 1661.0 1825.1    WY: CFS
 COLO321        1 1982    2 3005.4 7539.510024.2 4647.6 2229.1 1914.3    WY: CFS

COLO320      85/04/24. 14.02.57.
TEMP. MODEL TO TIME SERIES LINK; PRESENT LEVEL LEVEL  DATA - 31 DEC 84
COLORADO RIVER  D           320.2 IRRIGATION DEMAND
 COLO320        2 1979    1 1627.9 1981.3 1878.4 1829.6 2115.6 2011.7    WY: CFS
 COLO320        2 1979    2 2189.7 7207.913286.3 3952.0  762.8 1240.2    WY: CFS
 COLO320        2 1980    1 1530.3 1746.1 1618.2 1572.6 1525.0 1401.9    WY: CFS
 COLO320        2 1980    2 1450.3  764.4 2851.9  665.2     .0 1206.6    WY: CFS
 COLO320        2 1981    1 1693.0 1678.8 1536.9 1767.8 1579.1 1808.5    WY: CFS
 COLO320        2 1981    2 1589.7 3987.810412.7 7351.0 2519.2 2769.5    WY: CFS
 COLO320        2 1982    1 1837.5 1845.9 1646.4 1563.7 1617.7 1724.2    WY: CFS
 COLO320        2 1982    2 2388.6 5753.9 8500.0 3671.1 1317.1 1359.8    WY: CFS

COLO286      85/04/24. 14.03.01.
TEMP. MODEL TO TIME SERIES LINK; PRESENT LEVEL LEVEL  DATA - 31 DEC 84
COLORADO RIVER  B           286.4 GUNNISON RIVER CONFLUENCE
 COLO286        3 1979    1 1627.9 1981.3 1878.4 1829.6 2115.6 2011.7    WY: CFS
 COLO286        3 1979    2 2189.7 7207.913286.3 3952.0  762.8 1240.2    WY: CFS
 COLO286        3 1980    1 1530.4 1746.1 1618.2 1572.6 1525.1 1401.9    WY: CFS
 COLO286        3 1980    2 1450.3  764.4 2851.9  665.2     .0 1206.6    WY: CFS
 COLO286        3 1981    1 1693.0 1678.8 1536.9 1767.8 1579.1 1808.4    WY: CFS
 COLO286        3 1981    2 1589.8 3987.810412.7 7351.0 2519.2 2769.5    WY: CFS
 COLO286        3 1982    1 1837.5 1845.9 1646.4 1563.7 1617.7 1724.2    WY: CFS
 COLO286        3 1982    2 2388.6 5753.9 8500.0 3671.1 1317.1 1359.8    WY: CFS

GUNN286      85/04/24. 14.03.03.
```

Figure 3. Example flow time series file (L5QTS).

```
COLO321       85/04/24. 14.02.53.
TEMP. MODEL TO TIME SERIES LINK; PRESENT LEVEL LEVEL  DATA - 31 DEC 84
COLORADO RIVER  H 1F        321.8 CAMEO GAGE
 COLO321       1 1979   1   11.3    3.8     .6    1.6    4.1    5.8    WY:AVGDEGS
 COLO321       1 1979   2   10.0    9.2   12.9   19.0   19.5   15.7    WY:AVGDEGS
 COLO321       1 1980   1   10.8    5.8    3.9    3.9    4.2    7.3    WY:AVGDEGS
 COLO321       1 1980   2   11.2   13.5   16.8   20.9   20.2   17.3    WY:AVGDEGS
 COLO321       1 1981   1   11.0    5.5    1.4     .1    1.3    7.0    WY:AVGDEGS
 COLO321       1 1981   2    9.2   12.0   13.1   17.6   19.9   15.7    WY:AVGDEGS
 COLO321       1 1982   1    9.9    4.4     .8     .5    1.3    5.2    WY:AVGDEGS
 COLO321       1 1982   2    9.1   11.5   13.7   18.5   19.2   15.3    WY:AVGDEGS

COLO320       85/04/24. 14.02.57.
TEMP. MODEL TO TIME SERIES LINK; PRESENT LEVEL LEVEL  DATA - 31 DEC 84
COLORADO RIVER  D           320.2 IRRIGATION DEMAND
 COLO320       2 1979   1   11.3    3.7     .6    1.6    4.2    5.9    WY:AVGDEGS
 COLO320       2 1979   2   10.0    9.2   12.9   19.0   19.6   15.8    WY:AVGDEGS
 COLO320       2 1980   1   10.8    5.8    3.9    3.9    4.2    7.4    WY:AVGDEGS
 COLO320       2 1980   2   11.3   13.6   16.9   21.4   20.3   17.3    WY:AVGDEGS
 COLO320       2 1981   1   11.0    5.5    1.3     .0    1.4    7.1    WY:AVGDEGS
 COLO320       2 1981   2    9.3   12.1   13.1   17.6   20.0   15.7    WY:AVGDEGS
 COLO320       2 1982   1    9.9    4.4     .8     .4    1.4    5.2    WY:AVGDEGS
 COLO320       2 1982   2    9.2   11.6   13.7   18.6   19.3   15.4    WY:AVGDEGS

COLO286       85/04/24. 14.03.00.
TEMP. MODEL TO TIME SERIES LINK; PRESENT LEVEL LEVEL  DATA - 31 DEC 84
COLORADO RIVER  B           286.4 GUNNISON RIVER CONFLUENCE
 COLO286       3 1979   1   11.6    3.0     .0    1.5    4.7    6.6    WY:AVGDEGS
 COLO286       3 1979   2   11.4   10.7   13.8   20.6   21.1   16.6    WY:AVGDEGS
 COLO286       3 1980   1   10.9    5.6    3.7    3.6    4.0    7.9    WY:AVGDEGS
 COLO286       3 1980   2   13.3   16.8   19.0   29.1   21.9   18.1    WY:AVGDEGS
 COLO286       3 1981   1   10.9    5.5     .8     .0    2.5    8.2    WY:AVGDEGS
 COLO286       3 1981   2   10.9   13.9   14.2   18.9   22.0   17.0    WY:AVGDEGS
 COLO286       3 1982   1   10.7    4.5     .2     .0    2.1    6.3    WY:AVGDEGS
 COLO286       3 1982   2   10.5   12.9   14.9   20.2   20.7   16.6    WY:AVGDEGS
```

Figure 4. Example temperature time series output file (L5TTS).

```
STREAM NETWORK TEMP. MODEL TO TIME SERIES MODEL LINKAGE

VERSION 1.0   85/04/24. 14.02.52.
FILES USED IN PROCESSING LINKAGE:
        KTRNSPT= OUTPUT FROM THE TEMPERATURE MODEL
        L5JCF  = LINKAGE JOB CONTROL FILE
        L5TTS = TEMPERATURE TIME SERIES OUTPUT FILE
        L5QTS  = FLOW TIME SERIES OUTPUT FILE
        MESSGS = JOB RUN INFORMATION, MESSAGES, ETC.
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
BEGIN PROCESSING TEMPERATURE MODEL OUTPUT FILE
FLOWS ASSUMED TO BE IN CMS
JOB CONTROL FILE: UPPER COLORADO RIVER BASIN--DIRECT TEST
COLORADO RIVER TO BELOW STATE LINE GAGE ONLY
FROM YEARS  1 TO  4, TIMES  1 TO 12
BEGINNING IN YEAR    0
COVERING  12 TOTAL NODES.
KTRNSPT FILE ASSUMED TO BE OK.
THE TEMPERATURE MODEL OUTPUT CONTAINS THE FOLLOWING NODES:

   NODE#   DESCRIPTION
    1 COLORADO RIVER  H 1F       321.8 CAMEO GAGE
    2 COLORADO RIVER  D          320.2 IRRIGATION DEMAND
    3 COLORADO RIVER  B          286.4 GUNNISON RIVER CONFLUENCE
    4 GUNNISON RIVER  H 1F       298.0 GRAND JUNCTION, COLORADO
    5 GUNNISON RIVER  T          286.4 COLORADO RIVER CONFLUENCE
    6 COLORADO RIVER  J          286.4 GUNNISON RIVER JUNCTION
    7 COLORADO RIVER  R          257.4 IRRIGATION RETURN
    8 COLORADO RIVER  C          249.4 HORSETHIEF CANYON
    9 COLORADO RIVER  O          225.3 BLACK ROCKS STUDY SITE
   10 COLORADO RIVER  V 1S       217.2 STATE LINE GAGE
   11 COLORADO RIVER  C          206.0 UPPER WESTWATER CANYON
   12 COLORADO RIVER  E          200.0 TERMINAL POINT

END OF PROCESSING TEMPERATURE MODEL OUTPUT FILE.
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
PROCESSING YOUR JOB CONTROL FILE:

    TEMP. MODEL TO TIME SERIES LINK; PRESENT LEVEL LEVEL  DATA - 31 DEC 84
    WY: CFS
     UNITS = WY: CFS
    FIRST YEAR =   79 BIAS =   79
    LAST YEAR  =   82
    MONTHS = 111111111111 CORRESPONDING TO TEMP MODEL
```

Figure 5. Example MESSGS report.

```
   NODES LIST
 1 COLORADO RIVER  H 1F        321.8 CAMEO GAGE
 2 COLORADO RIVER  D           320.2 IRRIGATION DEMAND
 3 COLORADO RIVER  B           286.4 GUNNISON RIVER CONFLUENCE
 5 GUNNISON RIVER  T           286.4 COLORADO RIVER CONFLUENCE
 6 COLORADO RIVER  J           286.4 GUNNISON RIVER JUNCTION
 7 COLORADO RIVER  R           257.4 IRRIGATION RETURN
10 COLORADO RIVER  V 1S        217.2 STATE LINE GAGE
12 COLORADO RIVER  E           200.0 TERMINAL POINT

    HABTS DATA FMT =    0
    TEMP REFERENCE =          AVG    .00 CELSIUS

END OF PROCESSING JOB CONTROL FILE.
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
BEGINNING TO GENERATE TIME SERIES      85/04/24. 14.02.53.

     NODE#   DESCRIPTION
-------------------------------------------------------------------------------

        1   COLORADO RIVER  H 1F       321.8 CAMEO GAGE
           = COLO321

TEMPERATURE (AVGDEGS) SUMMARY FROM WY:1979 TO 1982
----------------------------------------------------
MONTH      1         2         3         4         5         6
-----
MINIMUM      9.86      3.77       .63       .06      1.29      5.18
AVERAGE     10.74      4.88      1.66      1.51      2.73      6.33
MAXIMUM     11.27      5.83      3.87      3.87      4.18      7.32

MONTH      7         8         9        10        11        12
-----
MINIMUM      9.11      9.16     12.90     17.55     19.18     15.30
AVERAGE      9.87     11.55     14.11     18.97     19.69     16.00
MAXIMUM     11.17     13.52     16.77     20.87     20.16     17.30

FLOW (CMS) SUMMARY
------------------
MONTH      1         2         3         4         5         6
-----
MINIMUM   1735.27   1719.16   1575.90   1602.70   1568.27   1502.69
AVERAGE   1877.11   1853.37   1708.99   1722.45   1752.60   1837.40
MAXIMUM   2042.42   2021.66   1917.41   1868.61   2158.85   2112.55

MONTH      7         8         9        10        11        12
-----
MINIMUM   2067.03   2550.05   4376.07   1642.57    910.73   1761.19
AVERAGE   2521.34   6214.13  10286.93   4886.99   2062.44   2198.60
MAXIMUM   3005.38   8993.55  14810.55   8328.38   3433.17   3324.09
-------------------------------------------------------------------------------
```

Figure 5. (Continued)

```
     .
     .
     .
     .
     .
     .
     .
-----------------------------------------------------------------------------

      12   COLORADO RIVER  E         200.0 TERMINAL POINT
         = COLO200

TEMPERATURE (AVGDEGS) SUMMARY FROM WY:1979 TO 1982
----------------------------------------------------
MONTH       1         2         3         4         5         6
-----
MINIMUM    12.26      7.18      4.29      5.28      8.35     10.26
AVERAGE    12.40      9.09      6.71      6.58      8.77     10.82
MAXIMUM    12.66     10.33      8.77      8.50      9.25     11.28

MONTH       7         8         9         10        11        12
-----
MINIMUM    12.34     12.88     14.75     16.68     13.96     13.92
AVERAGE    12.65     13.67     15.07     17.13     15.49     14.39
MAXIMUM    13.43     14.12     15.61     17.89     17.88     15.46

FLOW (CMS) SUMMARY
------------------
MONTH       1         2         3         4         5         6
-----
MINIMUM   5566.10   5449.32   4571.78   5522.17   7073.70   6112.68
AVERAGE   7111.99   6914.57   5504.43   6155.84   7973.51   7567.39
MAXIMUM   8167.39   9252.25   6632.28   6448.12   9799.75   8726.15

MONTH       7         8         9         10        11        12
-----
MINIMUM   6281.94   9564.63  14896.57   7579.60   9213.48   8988.21
AVERAGE  10459.51  24045.89  26837.45  14693.50  10555.50  10950.69
MAXIMUM  12633.76  36982.88  36868.85  20798.46  11876.57  13601.91

DATA IS ON FILES "L5TTS" AND "L5QTS"

END OF TIME SERIES GENERATION

THERE WERE   0 FATAL ERROR(S) IN THIS RUN

     AND   2 WARNING ERROR(S).
```

Figure 5. (Concluded)

2.5 Defaults

The only default conditions used in LNKT2TS pertain to the job control file. If data in that file are out of range then the defaults are to use the first and last years of temperature model data and use all months. If there are no nodes in the nodes list or an unexpected end-of-file is reached, then the program stops with a fatal error.

The default temperature time series (L5TTS) and flow time series (L5QTS) data files format is USGS.

3.0 RELATED SOFTWARE

3.1 Precursors

The temperature model, which is beyond the scope of this documentation, is the only precursor to running LNKT2TS.

Temperature model. When setting up your temperature model data set you must remember to account for the physical habitat sites in the network description. General guidelines would call for establishing a node wherever there is likely to be a change in flow of greater than 10 percent through a habitat site. Example input data to the temperature model are presented in Attachment 1.

3.2 Postcursors

None.

3.3 Alternate Methods

None.

4.0 LIMITATIONS

4.1 Accuracy

The water temperature predictions for maximum and minimums are not as good as for average. Maximum and minimum temperatures depend on calculation of travel time and depend on whether you are downstream from a junction or reservoir. If possible, avoid use of maximum and minimum relationships.

4.2 Assumptions

LNKT2TS assumes that the temperature model flows are in units of cubic meters per second.

Though calculations are independent of any given time step, the output files do assume monthly format.

4.3 Constraints

Current program limits are listed as follows. However, most limits may be changed by altering the parameter statements in the source code and recompiling.

Maximum Number of Nodes	35	
Maximum Number of Years	none	
Maximum Number of Time Steps/Year	12	
Minimum Number of Time Steps/Year	12	- should not be changed

5.0 MESSAGES

Messages are divided into two categories, warning and fatal. These are listed separately, approximately in the order in which they might be encountered. In general, warning messages will not cause program termination; the job will do its best to continue. Fatal errors, however, will cause either immediate or delayed job termination, depending on the circumstances. The output file (OUTPUT) will provide a run summary for these messages. The messages file (MESSGS) will show the messages in their entirety.

5.1 Warning Messages

1. *** WARNING *** THE FIRST YEAR REQUESTED ___ IS OUT OF BOUNDS OF TEMP.MODEL DATA. I WILL START WITH THE FIRST YEAR OF TEMP. MODEL INSTEAD.

   You probably put 1960 instead of 60, for example.

2. *** WARNING *** THE LAST YEAR REQUESTED ___ IS GREATER THAN THE LAST YEAR OF TEMP. MODEL DATA ___. I WILL END WITH THE LAST YEAR OF TEMP. MODEL INSTEAD.

   Ditto above.

3. *** WARNING *** YOUR REQUESTED MONTHS WERE BLANK. YOU SHOULD SPECIFY THEM. I WILL PROCEED WITH THEM ALL TURNED ON.

   Check the format for the species line in file L5JCF.

4. *** WARNING *** THE MAXIMUM NUMBER OF ___ NODES HAS BEEN EXCEEDED. THE FOLLOWING NODE:

   ____

   WILL NOT BE INCLUDED IN PROCESSING.

   Processing will continue with the maximum nodes.

5. *** WARNING *** THE FOLLOWING NODE:

   ____
   IS INVALID OR NOT FOUND - IT WILL BE EXCLUDED FROM PROCESSING.

   You possibly asked for a non-existent node. Also check for spelling and/or formatting errors in L5JCF.

6. *** WARNING *** ILLEGAL FORMAT REQUESTED. I WILL DEFAULT TO 0.

   Probably a typo or wrong column in L5JCF.

7. *** WARNING *** ILLEGAL BENCHMARK REFERENCE. REFERENCE RESET TO AVG.

   Expected MIN, AVG, or MAX in job control file. Check for proper format ___.

8. *** WARNING *** FOUND ___ INSTEAD OF PROPER UNITS.

   Consult units tables for legitimate options.

5.2 Fatal Messages

1. $$$ FATAL ERROR TEMPERATURE MODEL OUTPUT CONTAINS ___ NODES. I ONLY HAVE ROOM FOR ___. I MUST STOP.

   Program limits are being exceeded. You must recompile with a new parameter statement.

2. $$$ FATAL ERROR: NO VALID NODES WERE FOUND IN L5JCF FILE. PROCESSING CANNOT CONTINUE.

   There must be at least one valid node in the L5JCF nodes list in order to execute this program. Check formatting and spelling in L5JCF.

3. $$$ FATAL ERROR $$$ UNEXPECTED END FOUND ON JOB CONTROL FILE. PROCESSING CANNOT CONTINUE.

   Check formatting of L5JCF file.

4. $$$ FATAL ERROR: PROBLEM WITH RANDOM FILE (KTRNSPT) IN SUBROUTINE QTTS.

   Problem reading temperature model output file (KTRNSPT).

6.0 TIME/COST

A run for 4 years at 9 temperature nodes may cost $85 the first time.

These estimates, of course, do not include time to set up and debug data files. Though difficult to estimate, please allow up to 2 days to really get started. This ignores setting up and running the temperature model.

7.0 UNUSUAL APPLICATIONS

None.

8.0 POSSIBLE MODIFICATIONS

None

9.0 SUPPLEMENTAL MATERIAL

See also the HYDROSS and TEMPERATURE MODEL documentation.

10.0 HARDWARE

1. Standard - Any system supporting standard FORTRAN 77.
2. Required peripherals - none.

11.0 ACKNOWLEDGEMENTS

Development of this program was paid for by U.S. Fish and Wildlife Service, Region 6 (Denver).

APPENDIX F

VARIABLE NAME DICTIONARY
VARIABLES USED IN LINKAGES

A REAL - INTERCEPT COEFFICIENT ON Q-HA CURVE DATA
ACCUM REAL - ACCUMULATOR ARRAY FOR ONE LIFE STAGE'S HABITAT AREA
AK1 REAL - TEMPERATURE MODEL PARAMETER
AK1D REAL - DITTO
AK1X REAL - DITTO
AK2 REAL - DITTO
AK2D REAL - DITTO
ALVPRS REAL - DITTO
AN REAL - DITTO
AREA REAL - TRANSLATION OF CFS TO HABITAT AREA IN 1000 SQ. FT.
AVGT REAL - AVERAGE REACH TEMPERATURE
B REAL - SLOPE COEFFICIENT ON Q-HA CURVE DATA
BAVG REAL - TEMPERATURE MODEL PARAMETER
BNODE CHAR*80- NODE NAME READ IN IN THE Q-HA DATA FILE
BTITLE CHAR*80- TITLE FROM JOB CONTROL FILE
CDVNR CHAR*3 - CHARACTER FORM OF HYDROSS DIVERSION NUMBER FROM RMATCH
CHKUNT SUBROUT- ROUTINE TO CHECK FOR LEGAL UNITS FROM JOB CONTROL FILE
CONRES REAL - CONTROL RESERVOIR DESCRIPTION
CRFTYP CHAR*3 - CHARACTER FORM OF RETURN FLOW TYPE FROM RMATCH
CRSTN CHAR*6 - CHARACTER FORM OF HYDROSS STN IN LINK RECORD RMATCH
CSTDES CHAR*6 - CHAR FORM OF STN (CTL PT) #'S AS READ FM HYDROSS ARRAY STA
CSTN CHAR*10- CHARACTER FORM OF HYDROSS STATION AS READ FM HYDOUT
CSTNOLD CHAR*10- PREVIOUS RECORD'S CSTN
CTLPT CHAR*6 - 6 CHAR CONTROL PT FM RMATCH USED FOR COMPARISON W/ CSTDES
CVTCMS REAL - ARRAY OF CONVERSION FACTORS FROM M3/MON TO CMS
DATE FUNCTIO- NON FORTRAN 5 FUNCTION TO RETURN DATE
DAYRAD REAL - TEMPERATURE MOD PARAMETER
DCONST REAL - DIVERSION CONSTANTS IN HYDROSS - IGNORED
DD REAL - DEGREE DAYS
DDBM REAL - DEGREE DAY BENCHMARK TEMPERATURE (DEGREES)
DDFUDGE REAL - DEGREE DAY ADJUSTMENT (DEGREES)
DDLB REAL - DEGREE DAY LOWER BOUND (DEGREES)
DDLR REAL - DEGREE DAY LOWER RESET (DEGREES)
DDMETHD CHAR*10- DEGREE DAY CALCULATION METHOD
DDREF CHAR*3 - DEGREE DAY REFERENCE (MIN AVG OR MAX)
DDSUM FUNCTIO- ROUTINE TO CALCULATE THE SUM OF DEGREE DAYS BY METHOD
DDTS SUBROUT- ROUTINE TO PRINT OUT DEGREE DAY TIME SERIES FILE
DDUB REAL - DEGREE DAY UPPER BOUND (DEGREES)
DDUR REAL - DEGREE DAY UPPER RESET (DEGREES)
DEBUG REAL - SWITCH CONTROLLING DEBUG OUTPUT

```
DELT      REAL    - TEMPERATURE MODEL DELTA T
DELX      REAL    - DELTA X DISTANCE DOWNSTREAM
DELXD     REAL    - DELTA X DISTANCE DOWNSTREAM
DEPTH     REAL    - DEPTH OF FLOW
DFLO      CHAR*10- DATE OF HYDROSS FLOW FILE CREATION
DIVDES    INTEGER- DIVERSION DESCRIPTIVE INFORMATION FM NETWORK
DLIT      REAL    - TEMPERATURE MODEL PARAMETER
DNET      CHAR*10- DATE OF HYDROSS NET FILE CREATION
DODS      CHAR*10- DATE OF HYDROSS OUTPUT FILE CREATION (RUN OF COMRUN)
DTBL      CHAR*10- DATE OF HYDROSS TABLE FILE CREATION
DUM       REAL    - DUMMY
DWNTMP    FUNCTIO- ROUTINE TO CALCULATE DOWNSTREAM TEMPERATURE
F         REAL    - MISC FACTOR
FCTR      REAL    - DITTO
FFLO      CHAR*7 - NAME OF FLOW FILE IN HYDROSS RUN
FHDR      REAL    - HYDROSS HEADER 6HHYDROSS
FLOGET    SUBROUT- SUBROUTINE TO GET HYDROSS FLOW DATA
FLOINIT   SUBROUT- ROUTINE TO CROSS REFERENCE CONTROL POINTS
FLONOD    REAL    - ARRAY OF FLOWS FOR HYDROLOGY NODES (LINKED FLOWS)
FLORF     REAL    - PACKED RETURN FLOW DESCRIPTIVE INFO FM HYDROSS NETWORK
FLOW      REAL    - FLOW ARRAY (CFS) IN CALCULATING USABLE AREA
FMTT      CHAR*80- FORMAT -- UNUSED
FNET      CHAR*7 - NAME OF NETWORK FILE FM HYDROSS
FNORM     REAL    - ARRAY OF FLOW NODE NORMALS
FODS      CHAR*7 - NAME OF HY2COM OUTPUT BINARY FILE
FREC      CHAR*10- FORMATTED RECORD VALUES FOR MONTHLY TIME SERIES
FTBL      CHAR*7 - NAME OF TABLE FILE FM HYDROSS
FUDGE     REAL    - DEGREE ADJUSTMENT FACTOR (DEGREES)
HEAD      REAL    - TEMPORARY VALUE FOR HEAD OF REACH IN KILOMETERS
HOLD      REAL    - TEMPORARY STORAGE OF BRANCH NODE FLOW FOR LATER SUM WITH
                   TRIBUTARY TERMINUS FLOW TO PRODUCE JUNCTION TYPE NODE Q
HTYP      CHAR*3 - ARRAY OF 4 TYPES OF HYDROLOGY NODE MATCHING PARAMS FROM
                   RMATCH RECORD...HTYP(1) = RECORD TYPE, IE. RF, DIV, IN ETC
                                    2  = DIV # OR RF #
                                    3  = "DIV" FOR RF NODE, "OUT" FOR S
                                    4  = DIV # FOR A GIVEN RF
HYDOUT    CHAR*7 - NAME OF HYDROSS BINARY FILE (SOURCE OF MODEL FLOW DATA)
I         INTEGER- INDEX
IABORT    INTEGER- FLAG TO TERMINATE PROGRAM UNDER CERTAIN CONDITIONS
IACT      INTEGER- ACTION CODE FROM HYDROSS - IGNORED IN THIS LINK
ICKR      CHAR*3 - USED TO DETERMINE USGS OR NWDC FORMAT
ID        INTEGER- INDEX
IDSTA     INTEGER- DIVERTING STN FM HYDROSS OUTPUT FILE HYDOUT
IDV       INTEGER- ARRAY OF HYDROSS DIVERSION NUMBERS AT A GIVEN STATION
IDVNR     INTEGER- DIVERSION # FM HYDROSS FILE HYDOUT
IERNR     INTEGER- FATAL READ/WRITE ERROR # ON RANDOM ACCESS SCRATCH FILE
IFM       INTEGER- FLAG FOR USGS OR NWDC FORMAT
IGT       INTEGER- ARRAY WHICH INDICATES WHETHER GAGING OR GAGING AND
                   TEMPERATURE DATA EXIST FOR EACH LIFE/NODE BEING PROCESSED
II        INTEGER- INDEX
IN        CHAR*10- DUMMY PARAMETER
```

INDEX	INTEGER-	RANDOM ACCESS RECORD NUMBER
INFLO	INTEGER-	HYDROSS NETWORK ARRAY OF INFLOWS - IGNORED IN THIS LINK
INITIAL	SUBROUT-	ROUTINE TO SET TEMPERATURE CONSTANTS
INTERP	INTEGER-	FLAG FOR TYPE OF INTERPOLATION USED IN Q-HA DATA (UNUSED)
INTFIL	CHAR*80-	INTERNAL FTN5 FILE USED FOR ENCODE/DECODE
IODDTS	INTEGER-	FILE # FOR DEGREE DAY TIME SERIES DATA
IOFF	INTEGER-	DUMMY
IOFLO	INTEGER-	FILE OF HYDROSS OUTPUT DATA
IOGAGE	INTEGER-	FILE # FOR GAGE DATA FLOW FILE
IOHDR	INTEGER-	FILE OF CONTROL POINT CORRESPONDENCE
IOHTS	INTEGER-	FILE FOR HABITAT TIME SERIES
IOJCF	INTEGER-	FILE OF JOB CONTROL INFORMATION
IOMSG	INTEGER-	FILE FOR OUTPUT MESSAGES
IOOUT	INTEGER-	FILE # FOR OUTPUT FILE
IOPT	INTEGER-	APPEARS UNUSED
IOQA	INTEGER-	FILE OF Q-HA CURVE DATA
IOSCR	INTEGER-	SCRATCH FILE OF HYDROSS DATA
IOSCRT	INTEGER-	SCRATCH FILE OF TEMPERATURE DATA
IOTMP	INTEGER-	FILE OF TEMPERATURE MODEL DATA (KRTNSPT)
IOTMPR	INTEGER-	FILE # FOR TEMPERATURE DATA FILE
IOTSI	INTEGER-	FILE # FOR TEMPERATURE SI DATA
IOUT	INTEGER-	OUTPUT FILE NECESSARY TO GET RUN-TIME DIAGNOSTICS
IRF	INTEGER-	INTEGER RF% FM HYDROSS
IRFSUB	INTEGER-	RETURN FLOW RECIEVING STN SUBSCRIPT FM HYDROSS FILE HYDOUT
IRFS1	INTEGER-	LOWEST STATION SUBSCRIPT TO WHICH A GIVEN DIVERSION'S FLOW RETURNS
IRFS2	INTEGER-	HIGHEST RETURN SUBSCRIPT
IRFTYP	INTEGER-	INTEGER RF TYPE FM HYDROSS
IRSTA	INTEGER-	RF RECIEVING STN SUBSCRIPT FM FLORF
IS	INTEGER-	4TH POSITION OF STADES - CONTAINS DIVERSION INDEXES
ISI	SUBROUT-	ROUTINE TO INTERPOLATE TEMPERATURE SI VALUES
ISTA	INTEGER-	STN INDEXES, 1=--> NSTA
ISTAK	INTEGER-	INDEX TO INDICATE # OF BRANCHES STACKED UP WAITING TO BE COMBINED TO MAKE JUNCTION NODES
IT	INTEGER-	5TH POSITION OF STADES
ITEMP	INTEGER-	TEMPORARY INTEGER VARIABLE
ITYEAR	INTEGER-	INDEX OF YEARS FOR TEMPERATURE DATA
ITYR	INTEGER-	INITIAL TEMPERATURE MODEL YEAR USED HERE TO FORCE OUTPUT
ITYR1,2	INTEGER-	BEGINNING AND ENDING YEARS OF TEMPERATURE DATA. READ FROM THE HEADER INFORMATION IN THE FORMATTED TEMPERATURE DATA FILE
IX	INTEGER-	INDEX
IYER	INTEGER-	YEAR
IYR	INTEGER-	INDEX OF YEARS
IYRBIAS	INTEGER-	YEAR OF START OF TEMPERATURE OUTPUT FILE KTRNSPT
J	INTEGER-	INDEX
JCPDIV	INTEGER-	INDEX OF DIVERSIONS AT A GIVEN CTL PT
JCPRF	INTEGER-	COUNTER OF # RF AT A CTL PT
JLYR	INTEGER-	LAST SNTEMP YEAR WITH "19" REMOVED USING MOD
JRF	INTEGER-	INDEX TO RF SUBSCRIPTS, 1=--> NRF
JSTA	INTEGER-	INDEX TO STATION SUBSCRIPTS, 1=--> NSTA

JSTRUC	INTEGER-	STRUCTURE SUBSCRIPTS, 1=--> # STRUCTURES
JTITLE	CHAR*80-	JOB TITLE FROM JOB CONTROL FILE
JTYP	INTEGER-	RECORD TYPE READ FM HYDOUT, I.E. JTYP = 11 IS NON-PROJ Q
JTYR	INTEGER-	FIRST SNTEMP YEAR W/ "19" REMOVED
JYR	INTEGER-	HYDROSS RUNNING YEAR COUNTER IN OUTPUT FILE
JYROLD	INTEGER-	PREVIOUS YEAR'S JYR
K	INTEGER-	INDEX
KDVNR	INTEGER-	DIVERSION # FROM RMATCH - CHECKED AGAINST IDNVR
KGNSHDR	CHAR*7 -	UNUSED
KGNSHUP	CHAR*7 -	UNUSED
KGNSHYD	CHAR*7 -	UNUSED
KGNSJOB	CHAR*7 -	UNUSED
KHEAD	CHAR*80-	DUMMY USED TO STRIP HEADS FROM TEMP MOD JCL & HDR FILES
KNH	INTEGER-	NUMBER OF HYDROLOGY NODES FM HDR TYPE FILE
KNSTEP	INTEGER-	NUMBER OF TIME STEPS PER YEAR IN THIS LINK
KNTMX	INTEGER-	MISC FACTOR
KRFTYP	INTEGER-	INTEGER VALUE OF RFTYPE FM RMATCH
KTYR	INTEGER-	INITIAL TEMPERATURE YEAR USED TO FORCE FULL OUTPUT
L	INTEGER-	INDEX
LD	INTEGER-	HYDROSS OUTPUT FILE HYDOUT CREATION DAY (PORTION OF DATE)
LIFE	INTEGER-	INDEX FOR LIFE STAGE
LM	INTEGER-	HYDOUT CREATION MONTH
LNKCTL	CHAR*7 -	LINKAGE CONTROL FILE NAME
LSAVE	INTEGER-	SAVED LIFE STAGE NUMBER
LSREC	CHAR*22-	BUFFER USED FOR LIFE STAGE DATA READ FROM JCF FILE
LT	INTEGER-	HYDOUT CREATION TIME
LTITLE	CHAR*60-	TITLE LINE IN LINKAGE CONTROL FILE
LTYR	INTEGER-	LAST YEAR OF SNTEMP DATA
LY	INTEGER-	HYDOUT CREATION YEAR
LYR	INTEGER-	HYDROSS LAST YEAR OF DATA AND/OR LAST YEAR OF LINK DATA
M	INTEGER-	MONTH INDEX
MAXYR	INTEGER-	LAST YEAR REQUESTED IN JOB CONTROL FILE
MCND	INTEGER-	MONTH COUNT OF YR END MONTH INPUT AS CAL YR MONTH # AND RESET TO BE AN OFFSET FACTOR IN CAL=--> WTR YR CONVER
MDAYS	INTEGER-	DAYS IN EACH HALF OF MONTH
MDTOT	INTEGER-	TOTAL DAYS IN TWO HALVES OF TWO MONTHS
MHREC	INTEGER-	ARRAY OF POSITIONS W/IN RMATCH RELATED TO A NODE
MINYR	INTEGER-	FIRST YEAR REQUESTED IN JOB CONTROL FILE
MM	INTEGER-	INDEX
MMO	INTEGER-	MONTH MINIMUM HABITAT VALUE REACHED
MODE	INTEGER-	1,2 OR 3 DEPENDING ON MIN, AVG OR MAX TEMPERATURE
MONTH	INTEGER-	MONTH NUMBER
MONTHS	CHAR*12-	ARRAY OF APPLICABLE MONTHS FOR LIFE STAGE/NODE, JAN = 1
MREC	INTEGER-	INDEX OF ARRAY RMATCH SUBSCRIPTS RELATED TO A GIVEN NODE
MRECNR	INTEGER-	CUM # OF MATCHING RECORDS
MSGFG	INTEGER-	MESSAGE FLAG TO SET FATAL ERROR IF RF MIS-MATCHED
MSTN	CHAR*6 -	MATCH STATION FM RMATCH RECORD
MTOT	INTEGER-	TOTAL MONTHS A LIFE STAGE IS ACTIVE IN RUN
MXCRS	INTEGER-	MAX # CTL RES FM HYDROSS - IGNORED
MXDIV	INTEGER-	MAX # DIVERSIONS FM HYDROSS - IGNORED
MXIFL	INTEGER-	MAX # INFLOWS FM HYDROSS - IGNORED

MXLS	PARAMET-	MAXIMUM NUMBER OF LIFE STAGES ALLOWED
MXNODE	PARAMET-	MAXIMUM NUMBER OF HYDROLOGY NODES ALLOWED
MXPWR	INTEGER-	MAX # OF POWER PLANTS FM HYDROSS - IGNORED
MXQA	PARAMET-	MAXIMUM NUMBER OF POINTS IN Q-HA CURVE DATA
MXRES	INTEGER-	MAX # RESERVOIRS FM HYDROSS - IGNORED
MXRF	INTEGER-	MAX # RETURN FLOWS FM HYDROSS - IGNORED
MXSI	INTEGER-	MAX # OF POINTS ALLOWED IN THE T-SI CURVE DATA
MXSTA	INTEGER-	MAX # OF STATION FM HYDROSS - IGNORED
MYR	INTEGER-	TEMPORARY COUNTER FOR YEAR
NAMDIV	CHAR*40-	ARRAY OF DIVERSION DESCRIPTIONS FROM HYDROSS
NAMIFR	CHAR*40-	ARRAY OF INSTREAM FLOW RQMT DESCRIPTIONS FROM HYDROSS
NAMSTA	CHAR*40-	ARRAY OF STATION DESCRIPTIONS FROM HYDROSS
NBNODE	INTEGER-	NUMBER OF NODES REQUESTED TO BE USED FROM THE JOB CONTROL
NCEFF	INTEGER-	NUMBER OF CANAL EFF. TABLES FROM HYDROSS
NCHAR	CHAR*1 -	A SINGLE CHARACTER
NCRES	INTEGER-	NUMBER OF CONTROL RESERVOIRS FROM HYDROSS
ND	INTEGER-	INDEX
NDAYSP	INTEGER-	NUMBER OF DAYS PER TIME PERIOD FOR DEGREE DAY CALCULATIONS
NDDRST	INTEGER-	NUMBER OF DAYS EXCEEDING DEGREE DAY THRESHOLD PRIOR TO RESET
NDIV	INTEGER-	NUMBER OF DIVERSIONS FROM HYDROS
NETNAM	CHAR*60-	TITLE OF NETWORK FILE FROM HYDROSS
NFE	INTEGER-	NUMBER OF FATAL ERRORS ENCOUNTERED IN PROCESSING LINK2 JOB
NFMT	INTEGER-	TYPE OF HABITAT TIME SERIES FILE TO BE CREATED
NGNODE	INTEGER-	NUMBER OF GAGE NODE INDEX
NGNODES	INTEGER-	NUMBER OF GAGE NODES
NGYR	INTEGER-	NUMBER OF GAGE DATA YEAR INDEX
NGYRS	INTEGER-	NUMBER OF GAGE DATA YEARS
NGYR1	INTEGER-	BEGINNING YEAR OF GAGE DATA
NGYR2	INTEGER-	ENDING YEAR OF GAGE DATA
NIFR	INTEGER-	NUMBER OF INSTREAM FLOW RQMT LOCATIONS IN HYDROSS NET
NINDX	INTEGER-	INDEXES OF NODES THAT USE INFO FROM A GIVEN HYDROSS NODE
NINFLO	INTEGER-	NUMBER OF INFLOWS IN HYDROSS NET (INCL RTN FLOWS)
NIO	INTEGER-	FILE # FOR OUTPUT
NLOSS	INTEGER-	NUMBER OF OTHER LOSS TABLES IN HYDROSS NET
NLS	INTEGER-	NUMBER OF UNIQUE LIFE STAGES IN Q-HA DATA FILE
NLSQA	INTEGER-	NUMBER OF POINTS IN Q-HA CURVE FOR EACH LIFE STAGE/NODE
NLSX	INTEGER-	NUMBER OF LIFE STAGES REQUESTED FOR OUTPUT - SEE NXLS
NMAT	CHAR*1 -	CHAR FORM OF NUMBER OF MATCHING RECORDS PER NODE
NMON	CHAR*3 -	STRING OF MONTH NAME ABBREVIATIONS
NNODEX	INTEGER-	NUMBER OF NODES REQUESTED FOR OUTPUT - SEE NXNODE
NNYR	INTEGER-	TOTAL NUMBER OF YEARS OF HYDROSS DATA ON SCRATCH FILE
NODE	INTEGER-	INDEX TO THE CONTROL POINTS
NODEREC	CHAR*80-	BUFFER USED FOR NODE DATA READ FROM JCF FILE
NODTYP	CHAR*8 -	TEMPERATURE MODEL NODE TYPE (EG H.S.R.D.C.Q.V.E.T.J.)
NORMS	INTEGER-	FLAG FOR GENERATION OF NORMALS (FM LINK CTL FILE)
NORMYDD	INTEGER-	YEAR OF NORMALS IN KTRNSPT FILE (ORDINAL)
NOW	INTEGER-	CURRENT YEAR IN OUTPUT PROCESSING
NPTS	INTEGER-	NUMBER OF INTERPOLATABLE POINTS IN Q-HA CURVE
NPWR	INTEGER-	# OF PWR PLANTS FM HYFROSS
NQA	INTEGER-	NUMBER OF POINTS IN Q-WUA CURVE FOR A LIFE STAGE/NODE
NR	INTEGER-	INDEX
NRCK	INTEGER-	# NODES FOUND IN SNTEMP HYDROLOGY NODE FILE

NRES	INTEGER-	# OF RESERVOIRS FM HYDROSS
NRF	INTEGER-	# OF RETURN FLOWS FROM HYDROSS
NRFD	INTEGER-	# OF RNT FLOW DELAY TABLES FM HYDROSS
NRFDIV	INTEGER-	# OF RF FROM CURRENT DIVERSION
NSAVE	INTEGER-	SAVED NODE NUMBER
NSEEP	INTEGER-	# OF SEEPAGE TABLES FM HYDROSS
NSI	INTEGER-	INDEX TO SI COORDINATE PAIR
NSTA	INTEGER-	# OF STATIONS IN HYDROSS NETWORK
NTIM	INTEGER-	TIME STEP INDEX
NTIMES	INTEGER-	NUMBER OF TIME PERIODS IN TEMP MOD KTRNSPT FILE
NTNODE	INTEGER-	NUMBER OF TEMPERATURE MODEL NODE (INDEX)
NTNODES	INTEGER-	NUMBER OF TEMP MOD NODES
NTTIM1	INTEGER-	LOWEST TEMP MOD TIME STEP
NTTIM2	INTEGER-	HIGHEST TEMP MOD TIME STEP
NTYP	INTEGER-	DUMMY PARAMETER
NTYR	INTEGER-	NUMBER OF TEMPERATURE MOD YEAR (INDEX)
NTYRS	INTEGER-	NUMBER OF TEMP MOD YEARS
NTYR1	INTEGER-	LOWEST TEMP MOD YEAR
NTYR2	INTEGER-	HIGHEST TEMP MOD YEAR
NUMAT	INTEGER-	NUMERICAL VALUE FOR # OF MATCHING RECORDS FOR A NODE
NWE	INTEGER-	NUMBER OF WARNING ERRORS ENCOUNTERED IN PROCESSING JOB
NWREC	INTEGER-	CALCULATED INDEX TO SCRATCH FILE FLOW DATA
NX	INTEGER-	INDEX
NXLS	INTEGER-	INDEX NUMBERS TO LIFE STAGES REQUESTED FOR OUTPUT
NXNODE	INTEGER-	INDEX NUMBERS TO NODES REQUESTED FOR OUTPUT
NYR	INTEGER-	HYDROSS FIRST YEAR OF DATA AVAILABLE
NYR1	INTEGER-	FIRST YEAR OF DATA WRITTEN TO SCRATCH FILE
OUT	CHAR*10-	DUMMY PARAMETER
PI	REAL -	VALUE OF PI
Q	REAL -	FLOW
QL	REAL -	LATERAL FLOW
QMIN	REAL -	TEMPERATURE MODEL PARAMETER
Q0	REAL -	DITTO
R	REAL -	UNSURE
RCONST	REAL -	RESERVOIR CONSTANTS FM HYDROSS - IGNORED
READJCF	SUBROUT-	ROUTINE TO READ JOB CONTROL FILE
READKT	SUBROUT-	ROUTINE TO READ KTRNSPT FILE
READQ	SUBROUT-	ROUTINE TO READ GAGE DATA
READQA	SUBROUT-	SUBROUTINE TO READ Q-HA DATA FILE
READTSI	SUBROUT-	ROUTINE TO READ TEMPERATURE SI DATA FILE
RECORD	CHAR*80-	GENERIC DATA INPUT CHARACTER IMAGE
REMARK	CHAR*48-	REMARKS FIELD FROM TEMP MOD NODE
REND	REAL -	REACH END (KILOMETERS)
REPORT	SUBROUT-	SUBROUTINE TO WRITE OUTPUT REPORT
RESAC	REAL -	RESERVOIR AREA - CAPACITY ARRAY FM HYDROSS - IGNORED
RESET	REAL -	SWITCH TO INDICATE DEGREE DAY RESET
REXP	REAL -	TEMPERATURE MOD PARAMETER
REXPMN	REAL -	DITTO
REXPMX	REAL -	DITTO
RHOCP	REAL -	DITTO
RMATCH	CHAR*80-	ARRAY OF LINKAGE MATCHING RECORDS

RMIN	REAL	TEMPERATURE MOD PARAMETER
RPWRC	REAL	RESERVOIR POWER PLANT CNSTANTS FM HYDROSS - IGNORED
SCALE	REAL	SCALE FACTOR
SF	REAL	TEMPERATURE MODEL PARAMETER
SI	REAL	SUITABILITY INDEX CALCULATED FROM CURVE
SIMETHD	LOGICAL	THIS VARIABLE IS SET TO TRUE FOR A LIFE STAGE TO BE PROCESSED WITH TEMPERATURE CONDITIONED TIME SERIES DATA. IT IS SET TO FALSE FOR NON-TEMPERATURE CONDITIONED DATA
SLAVG	REAL	LIFE STAGE AVERAGE HABITAT VALUE ENCOUNTERED (SQ. FT.)
SLDEG	REAL	DEGREE COORDINATES OF TEMPERATURE SI PAIR
SLDIST	REAL	DISTANCE DOWN FROM NODE FOR Q-HA RELATIONSHIP (1000 FT)
SLIFE	CHAR*20	SPECIES NAME (1:10) LIFE STAGE NAME (11:20)
SLOPE	REAL	SLOPE OF LINEAR INTERPOLATION
SLQ	REAL	DISCHARGE COMPONENT OF Q-HA FOR A LIFE STAGE/NODE (CFS)
SLSTAT	REAL	ARRAY TO HOLD STATISTICS FOR A LIFE STAGE
SLTDAT	REAL	LIFE STAGE TEMPERATURE DATA
SLTEMP	CHAR*12	ARRAY OF TEMPORAL APPLICABILITY FOR Q-HA DATA
SLTHRS	REAL	MINIMUM HABITAT VALUE (SQ. FT.) FOR LIFE STAGE/NODE WARNING
SLTSI	REAL	LIFE STAGE TEMPERATURE-SI CURVE
SLWUA	REAL	HAB. AREA PART OF Q-HA FOR LIFE STAGE/NODE(SQFT/1000SQFT)
SNORM	REAL	ARRAY TO HOLD S NODE NORMAL OUTFLOW (INFLOW IN FNORM)
STADES	INTEGER	PACKED STATION DESCRIPTION ARRAY FM HYDROSS - USED
STDUM	CHAR*6	DUMMY STATION NUMBER FROM TIME SERIES FILE
STITLE	CHAR*60	HYDROSS STUDY TITLE
STRDIS	REAL	STREAM DISTANCE FROM NODE DESCRIPTOR
STRNAM	CHAR*16	STREAM NAME FROM NODE DESCRIPTOR
STRUC	REAL	STRUCTURE NODE OUTFLOW (INFLOW TO FLONOD)
SUM	REAL	TEMPORARY SUM TO COUNT THINGS UP
T	REAL	ARRAY OF TEMPERATURE DATA FROM SCRATCH FILE
TABSO	REAL	TEMPERATURE MOD PARAMETER
TAIL	REAL	TAIL OF SUB REACH IN KILOMETERS
TAREA	REAL	TOTAL AREA
TAVG	REAL	AVERAGE PREDICTED TEMPERATURE
TE	REAL	TEMPERATURE MODEL PARAMETER
TED	REAL	DITTO
TEMP	REAL	TEMPORARY VALUE HOLDER
TEMPER	SUBROUT	ROUTINE TO FACTOR TEMPERATURE SI INTO WUA
TEP	REAL	TEMPERATURE MOD PARAMETER
TEX	REAL	DITTO
THNOD	CHAR*80	NODE IDENTIFIER
TIME	FUNCTIO	NON FORTRAN 5 ROUTINE TO PROVIDE THE DAYTIME
TL	REAL	TEMPERATURE MOD PARAMETER
TMAX	REAL	MAXIMUM PREDICTED TEMPERATURE
TMIN	REAL	MINIMUM PREDICTED TEMPERATURE
TMPINIT	SUBROUT	SUBROUTINE TO CHECK CONTROL POINT CROSS-REFERENCES
TMPNORM	FUNCTIO	ROUTINE TO CALCULATE NORMAL TEMPERATURE FOR TIME STEP
TMPVAL	FUNCTIO	ROUTINE TO GET A TEMPERATURE VALUE FROM RANDOM FILE
TNOD	CHAR*80	ARRAY OF TEMPERATURE DATA NODE IDENTIFIERS. IDENTIFIERS ARE ADDRESSED EQUIVALENT TO THOSE IN THNOD
TOLNCE	REAL	HYDROSS ERROR TOLERANCE PARAMETER - IGNORED
TOLRN	REAL	MISC FACTOR

TPNOD	CHAR*80-	ARRAY OF TEMPERATURE DATA NODE IDENTIFIERS. IDENTIFIERS ARE ADDRESSED EQUIVALENT TO THE ORDER THEY ARE READ INTO THE PROGRAM FROM THE DATA FILE
TSAMPLE	REAL -	TEMPERATURE SAMPLE DISTANCE (KILOMETERS)
TTITLE	CHAR*80-	TITLE FROM TEMP MOD DATA FILE (KTRNSPT)
TW	REAL -	TEMPERATURE MOD PARAMETER
TWAVG	FUNCTIO-	ROUTINE TO CALC AVG WATER TEMPERATURE
TWD	REAL -	TEMPERATURE MODEL PARAMETER
TWMAX	FUNCTIO-	ROUTINE TO CALC MAXIMUM WATER TEMPERATURE
TWX	REAL -	TEMPERATURE MODEL PARAMETER
TYP	CHAR*1 -	NODE TYPE FROM SNTEMP NODE RECORD THNOD
T0	REAL -	MISC FACTOR
T0X	REAL -	DITTO
T1	CHAR*20-	TEMPORARY STRING
T2	CHAR*3 -	DITTO
UNITS	CHAR*10-	UNITS STRING
UNITS	CHAR*6 -	UNITS STRING IN CHKUNT ROUTINE
VAL	REAL -	ARRAY OF FLOW DATA FROM SCRATCH FILE (CMS)
VAPRS	REAL -	TEMPERATURE MOD PARAMETER
WRITE10	SUBROUT-	SUBROUTINE TO WRITE HABITAT TIME SERIES DATA FILE
WRITHTS	SUBROUT-	ROUTINE TO WRITE HABITAT TIME SERIES
WUA	SUBROUT-	SUBROUTINE TO CALCULATE WEIGHTED USABLE AREA
X0MAX	REAL -	MISC TEMPERATURE FACTOR
YEAR	CHAR*3 -	YEAR STRING
YROUT	SUBROUT-	SUBROUTINE TO WRITE SCRATCH FILE OF CROSS-REFERENCED FLOW

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16. Abstract (Limit: 200 words)

In recognition of the need to assess and manage combined environmental effects of man's activities in aquatic ecosystems the computer based tools within the Instream Flow Incremental Methodology (IFIM) have been extended to incorporate spatial and temporal cumulative effects. This document serves as an introduction to the use of computer based models in evaluating such effects, a guide to analysts encountering cumulative effect problems, and as documentation of a group of computer programs designed to assist in cumulative effect analysis when the use of a monthly time step, steady state analysis is appropriate. The topics covered include a general description of the use of computer models in decision support, discussion of considerations for scoping a Stream Network Habitat Analysis, description of potential costs and problems that may be encountered, and an example of the first iteration of such an analysis. The extensive appendixes contain user documentation of specific computer programs developed by the Instream Flow Group to deal with monthly time step, steady state analysis of habitat in riverine systems. The manual is intended to serve readers with widely varying degrees of experience with this class of problems, and suggestions are provided regarding the portions of the text best suited to each reader's experience level.

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END

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